

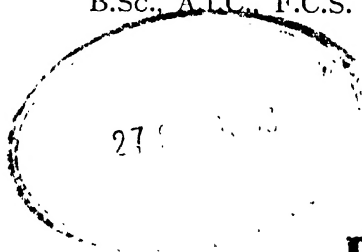
## REFERENCE

# COMMERCIAL COMMODITIES

BY

FRANK MATTHEWS

B.Sc., A.L.C., F.C.S.



**REFERENCE**



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# REFERENCE

## PREFACE

THE purpose of this book is to give to the student and the general reader a not too detailed idea of the more important raw, or semi-manufactured, articles used in trade. It is no part of the aim of the work that it should pretend to instruct the skilled craftsman or technician concerning the material used by him in his own particular avocation. It should, however, be able to inform him on allied subjects.

A special study of any particular commodity must entail consultation of works specifically on that subject or of books of wider scope than this. Amongst such could be recommended the admirable "Common Commodities and Industries Series," issued by the publishers of this volume; "The Westminster Series"; Dr. Hutchinson's *Food and Dietetics*; Thorpe's *Dictionary of Applied Chemistry*; and the weekly "Trade Supplement" to *The Times*.





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# COMMERCIAL COMMODITIES

## SECTION I—GENERAL

### CHAPTER I

#### INTRODUCTION

**NATURE OF COMMODITIES.**—A commodity has been defined as a thing used in trade, and that definition will suffice as the subject matter of this volume. The following chapters then will treat of things used in trade. Before, however, we can commence with any separate article of trade it will be necessary to inquire into the limits of our subject. For instance, labour is certainly used in trade. In production it is probably the chief concern, and it occupies a very high place in the cost and process of distribution. As a rule labour is the one thing which the workman has to sell, his only saleable commodity, and in order to get the best price for his article he will proceed in a similar way to that in which a man with, say, cotton for sale would do. He will make a price list, a very short one it is true, combine with other persons having similar labour to sell as to the minimum prices, hours of sale, etc., and will seek to keep out of the market all others who sell labour on terms disadvantageous to him. Nevertheless, it is not proposed to include labour as a separate commodity in this book; its treatment is one of the functions of economics, and it will only be dealt with here in so far as it is an important item in the production of concrete articles, which have definite physical characteristics, *e.g.* weight.

**CLASSIFICATION.**—There are many possible ways of classifying these thousands of concrete things which can be used in trade. One could proceed on a logically scientific basis having a scheme which would start with astronomy, passing to geology, botany, zoology, geography, and so on, and then having formulated the general plan proceed to select such articles as were useful in trade for special treatment. It is doubtful, however, whether the study

of commodities is as yet old enough or general enough to warrant such a method, and in any case the author in this instance is working to a scheme which is, in its general idea, psychological rather than logical; it groups things in known and accepted ways, and has the great advantage, therefore, of appealing to a body of knowledge already present in the mind of the student and marching with many of his preconceived ideas. There will therefore be very little that the student will have to undo and most of his study will be purely constructive.

**VALUES AND TESTS.**—This, however, does not preclude the necessity of being scientific, and as terms and ideas of physical science will constantly be used in the treatment of our subject it will be necessary at the outset to give a short time to their consideration.

Commodities are valuable for their form, colour, taste, smell, texture, hardness, porosity, durability and resistance to corrosion, density, electrical properties, optical properties, food value, therapeutic value, etc., and the value of a commodity usually depends, in part at any rate, on the possession of one or more of these qualities.

It therefore becomes necessary to assess the measure in which any valuable quality is held by a commodity, and wherever this is possible it is done objectively, *i.e.* in a manner which does not involve the opinion or personal character of the tester.

Physical or chemical methods will therefore be employed, and the process of testing will be as mechanical as possible.

As an example, we might instance the fact that whereas at one time the strength and composition of steel used to be judged from its appearance in manufacture, nowadays in addition to that judgment by appearance the manufacturer and the purchaser use, in order thoroughly to test it, the much more detailed and exact micro-photograph as well as the actual strength necessary to break the steel and the actual percentage quantities of the different elements which compose it.

In some cases, however, even to-day no mechanical test is possible, and the estimate of quality is a purely personal one. Thus, the chemical compound or compounds which make the difference between a good and an inferior tea are not yet known, and the goodness of tea is not measurable by any means except the personal opinion of men (*viz.*, tea-tasters) who are used to evaluating teas.

## INTRODUCTION

**UNITS AND TERMS.**—Where, however, the quality of the commodity is expressible in physical terms this is usually done, and it is desirable that all persons dealing in goods of such types should, at least, know the meaning of the terms employed, if not, indeed, be acquainted with the actual process of testing. In order, therefore, that the student may understand the more generally used physical constants a list of them is included here with a brief explanation of each one.

1 metre = 39·37 inches.

approximately therefore 1 ft. = 30 centimetres.

1 gram = wt. of 1 cubic centimetre of water at its maximum density, *i.e.* at 4° Centigrade or 39° Fahrenheit.

28·35 grams, or approximately 30 grams = 1 oz. avoirdupois.

or 1,000 grams, *i.e.* 1 kilogram = 2½ lbs. "

1,000 ccs., *i.e.* 1 litre = 1¾ pints "

1 metric ton = 1,000 kilograms.

= 2,205 lbs.

1 short ton = 2,000 lbs.

1 long ton, *i.e.* the ordinary ton of English commerce = 2,240 lbs.

**Density** = the weight, in grams, of 1 cubic centimetre of the substance ; practically it is the weight as compared with that of an equal volume of water. Thus a substance which is 5½ times as heavy as the same volume of water has density 5·5.

**Hardness.** This is often a very important property, but as yet it cannot be measured exactly, all that has been done is to make a list of 10 solids of varying degrees of hardness and compare all others with them, they are as follows—

Talc (the softest) . . . . .	1
Crystallized Gypsum . . . . .	2
Calcspars . . . . .	3
Fluorspar . . . . .	4
Apatite . . . . .	5
Felspar . . . . .	6
Quartz . . . . .	7
Topaz . . . . .	8
Sapphire . . . . .	9
Diamond . . . . .	10

A body which would scratch quartz but would be scratched by topaz is said to have hardness 7·5.

**Calorie.** The amount of heat necessary to raise the temperature of 1 gram of water 1° Centigrade.

**Food Value.** This is generally expressed by the amount of heat, *i.e.* number of calories, given out in converting 1 gram of the given food to the form which it assumes by the time it is completely digested.

**Calorific Value.** The amount of heat, *i.e.* number of calories given out on completely burning 1 gram of a given fuel.

There are, of course, many other units and terms employed but the above are more frequently used ; any others necessary will be explained in the text.



## CHAPTER II

### METHODS OF PRESERVATION

Most substances undergo change if kept for any length of time. There are two main causes of this—

- (i) *Changes due to living organisms.*
- (ii) *Changes due to the atmosphere, water, etc.*

In general bodies are not improved by these changes, although this is not invariably the case. Brandy, for example, when kept under the appropriate conditions undergoes chemical changes which greatly increase its quality and value. Such cases are however exceptions, and we generally use such terms as *tarnished*, *rotten*, *rancid* or *bad* to indicate the undesirability of the changes which most substances undergo.

This property of most articles of merchandise, combined with the fact that the increasing complexity of modern life makes it necessary to draw upon the whole world for the upkeep of a single member of a civilized society, has diverted a very large amount of capital, labour and ingenuity to the problem of how best to keep articles in the most desirable condition. This result is so much sought after and the means adopted are so varied that it seems best to devote a chapter to the consideration of the chief means of preservation.

(a) **DECOMPOSITION DUE TO LIVING ORGANISMS.**—The obvious way to deal with such cases is either to prevent the intrusion of the harmful bacilli, etc., or if they are already present to destroy them. It is, further, often necessary to render the commodity difficult or impossible of access to the organic agent of putrefaction. Some of the methods of securing these ends are—

(i) **Boiling.**—Bacteria, etc., are very sensitive to temperature changes and all of them are killed at a moist temperature of 100° C. It is therefore sufficient to keep the article to be sterilized at the boiling point of water for a few minutes in order completely to destroy all living matter as well as spores. This method is applicable in all cases where the value of the substance to be preserved is not appreciably diminished by the temperature changes involved. In particular it is useful in the preservation of all foods which are to

be sold ready cooked. In fact, one of the results of cooking is almost always sterilization.

(ii) **Pasteurizing.**—In certain cases it is deleterious to boil the article which is to be preserved, and it is then sometimes sufficient to raise the temperature to about  $160^{\circ}\text{F.} = 71^{\circ}\text{C.}$  While this moist temperature is always great enough to kill the decay germs it does not always destroy the spores, and these will develop under favourable circumstances (for them) : but the operation in many cases prolongs the goodness of the substance sufficiently for practical purposes.

Milk is one of the foodstuffs which is better “Pasteurized,” as this treatment is called, than boiled, since boiling renders it less digestible, whereas pasteurizing does not.

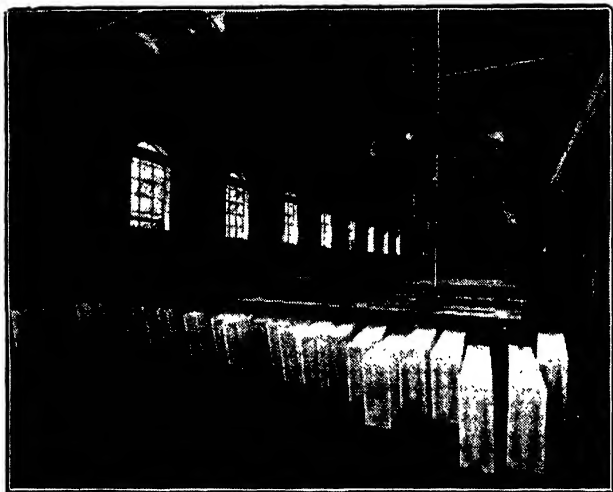
(iii) **Boiling with Sugar.**—Another special instance of this principle is that of boiling with sugar. Cane sugar will not permit the growth of ferments and by sterilizing fruit, etc., by boiling and, in addition, impregnating with a large percentage of the non-fermenting cane sugar present, “preserves,” as they are called, can be made which will keep good for a long time.

(iv) **Canning and Bottling.**—The previous methods are, as a rule, only sufficient when the article to be preserved is to be consumed almost immediately. We are all familiar with the fact that cooked meat, as well as raw, will go bad. Sterilization by boiling is therefore usually carried out in conjunction with some additional process which guards the sterile subject from future contamination. This is effected by covering with a coating impervious to the agents of decomposition and most frequently by enclosing the substance in a box of tinned iron or else a glass or earthenware bottle. Either the containing vessel is sealed with its contents before putting in the sterilizing bath or else it is sealed whilst at the boiling temperature. By such means food can be kept for a very long time, although perhaps not indefinitely. In any case tinned food has been known to go bad although the cause is not known with certainty. The condensed milk which kept so badly in tins during the war was perhaps affected by the flux used in soldering or by the solder itself.

(v) **Coating.**—A special case of the previous general method is that of coating the substance with oil or fat, as for instance, in

certain potted meats and in chilled meats which are usually immersed in cotton seed, or some similar oil.

The idea of the impervious unattacked outside layer is also illustrated by the practice of coppering ships to prevent the attachment of barnacles, etc., and also in painting, which process, amongst other things, makes wood difficult of access for the bacteria causing wood to rot.



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#### ICE-MAKING PLANT

(vi) **Refrigeration.**—Whilst bacteria are destroyed by boiling they are at least prevented from developing by cold. It should be noted, however, that cold is not nearly so destructive of life as is heat. Seeds which have been kept for a long time at the temperature of liquid air  $-180^{\circ}\text{C}.$ , have still germinated when put under the appropriate conditions.<sup>1</sup> Cold however does, as a rule, prevent the breeding and increase of germs, and since it does not prejudicially affect the flavour of foods in the way that boiling may do it has a very great vogue as a preserving agent. Incidentally, it should be noticed that cold does not “cook” foods, and this is, of course, an additional point in its favour in many instances. It is sometimes

<sup>1</sup> The results of these experiments have quite recently been questioned.

## METHODS OF PRESERVATION

sufficient, where the goods are small in quantity and do not require to be kept for a long time, merely to have a quantity of ice present in the room or case containing the article, but, for prolonged storage in bulk, refrigeration is always necessary.

The principle involved is that when a gas increases in volume it must expend energy in so doing. This energy is usually derived from heat, and, if the expansion be sufficiently rapid, the heat will be taken from the gas itself. Hence, by allowing a compressed gas to expand rapidly it will be cooled. In practice, for refrigeration, ammonia gas is alternately compressed and expanded until it becomes liquid. This liquid ammonia is then allowed to boil, which it will do on releasing the pressure. The very cold ammonia gas which results from this evaporation is made to cool a strong solution of salt in water which is led in pipes round the room to be cooled, returns to the cooling machine where it is recooled, again passes through the pipes, and so on. This system of cooling is thus precisely analogous to the pressure hot water system of heating. The actual room temperatures reached are in the neighbourhood of  $15^{\circ}$  F., or about  $-10^{\circ}$  C. Under such conditions most food will keep good almost indefinitely, proof being furnished by the fact that mammoths frozen in the Siberian tundra for centuries, perhaps thousands of years, have been readily devoured when dug out, by dogs and even by the native tribesmen!

Refrigerated foods, however, require very careful cooking if they are to be really palatable, and in any case are apt to be impaired in flavour, and therefore attempts have been made to preserve foods at a greater temperature than that required for refrigeration. This process is called "chilling," and is applied chiefly to meat. In order, however, that the meat shall keep good at the temperature required, *i.e.*  $29^{\circ}$  F. or  $-2^{\circ}$  C., it has to be coated with some material, *e.g.* oil, impervious to air. At first the oil used introduced unpleasant flavours, but the problem is now considered to be settled satisfactorily.

It should be noted that if the cold room contained water this would be converted into ice, and this is in principle the way in which ice is manufactured.

(vii) **Desiccation.**—It has been mentioned that a moist heat is necessary to destroy bacteria, and it may seem rather paradoxical

to say that moisture seems to be necessary for their generation. It is a familiar experience that things go bad very quickly in warm damp weather, whereas in hot dry weather they may keep for a long time. In fact certain native methods of preserving meat depend upon exposing it to hot sun. The drying, or desiccation, of perishable articles has now come to be a frequently used method of preservation, especially for fruits, *e.g.* currants, dried peaches, apple rings, etc.; fish are also preserved in this way, especially in Norway.

(viii) **Germ Poisoning.**—Bacteria, like all other living things, can be poisoned, and once substances can be discovered which will poison micro-organisms and at the same time be innocuous as far as human life is concerned the preservation of all foods should be a very simple matter. Unfortunately no such substance is known, although there are several which are of no great harm. The chief of these is boric acid, or boracic acid as it is frequently called. This substance is used principally to prolong the “freshness” of very quickly perishable articles such as milk and cream. It is not, however, quite harmless to human life, and milk preserved by its aid is probably injurious when it forms a large part of the diet, as, for instance, in the food of typhoid patients and babies.

Another illustration of germ poisoning is in the spraying of standing crops to prevent disease and “blight.” Here it is not necessary to be so particular as to the germicide used and much more satisfactory results have been obtained. Wood is prevented from rotting by impregnating it, under pressure, with creosote, a very powerful germ killer or antiseptic.

**Renovation.**—Whilst great attention is known to be paid to the preservation of perishables it is not so generally known that there is a good deal of renovation, *i.e.* removal of signs and products of decomposition in articles that have already gone bad. Naturally these processes are kept secret whenever possible, but now and again some light is thrown upon their use. Tainted meat is washed or rather dabbed with a weak solution of potassium permanganate, and the acids, *e.g.* butyric acid, which are produced on keeping butter too long and which are the cause of its rankness or rancidity, are removed by washing with alkali. Such cases as the foregoing are quite legitimate, but where the method of renovation is merely

that of adding some strong flavour to "drown" the usually unpleasant taste of the decomposed food we are face to face with fraud, or worse.

**Destruction of Vermin.**—In addition to the attacks of micro-organism goods are subject to attack by macro-organisms—larger living things such as rats, beetles, etc. The only safe way of dealing with such creatures is to protect the substances liable to attack, and this is usually done by enclosing them in metal. Of course, there are ways of discouraging the pests, but as yet they are far from satisfactory. Probably the line of advance will be in the direction of discovering some epidemic diseases to which the vermin alone will be susceptible. Another possible method is by developing the "gas attack" and poisoning the animals by means of gas released at favourable times when the stores, etc., are empty of food.

(b) **DETERIORATION DUE TO NON-LIVING CAUSES.**—The best known example of deterioration of this type is that of the rusting of iron. Generally speaking, tarnishing and rusting are due to the presence of oxygen, carbon dioxide, moisture and sulphur compounds in the atmosphere, oxides, carbonates and sulphides being formed. The actual decomposition products resulting in individual cases will be dealt with under the headings of the different commodities, but the general methods of dealing with the problem can be indicated here. They are—

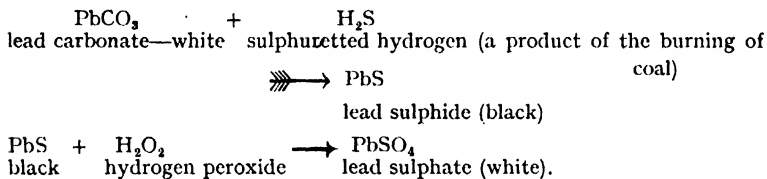
(i) **Dryness.**—Rusting takes place with great difficulty, if at all, in a perfectly dry atmosphere.

(ii) **Coating.**—The use of a protective coating, *e.g.* oil, or in the case of iron girders, cement. Paints come under this heading. Plating is a further illustration of this method. Sometimes this protective coating is afforded by allowing the material to tarnish and to remain tarnished. Copper can be preserved from attack in this way.

(iii) **Cleaning.**—In many cases the action is cumulative. Every one knows, for instance, that once iron has begun to rust it continues to do so at an increasingly rapid rate. The removal of the rust is therefore a very good way of helping to prevent further rusting.

(iv) **Restoration.**—The conversion of the tarnish into some other non-deleterious substance, *e.g.* picture restoring. This may

as well be explained fully as it will not be mentioned again. Pictures go black because the white lead (basic lead carbonate) which forms the body of the paint is changed to black lead sulphide by the action of the sulphuretted hydrogen, from coal and gas, in the air. But the black lead sulphide can very easily be converted into white lead sulphate by hydrogen peroxide. Washing the blackened picture with a solution of this substance, therefore turns the black into white and the colours, no longer obscured, are again in evidence. Thus—



(v) **Defect in Manufacture.**—Sometimes the decomposition is due to defect in manufacture and then practically nothing can prevent decay. This is sometimes the case, for instance, in aluminium which may contain sodium, and if it does galvanic action is almost bound to take place and will result in the disintegration of the aluminium. Glass sometimes breaks down owing to its becoming crystalline, and certain fine old stained glass windows are doomed beyond hope because of crystallization.

(vi) **Desiccation** may cause deterioration, and this may be due to removal of water or the formation of solid substances out of liquid oils. A familiar example of deterioration due to desiccation is in boot polish and in tobacco.

(vii) **Deliquescence.**—The taking up of water, *i.e.* deliquescence, is also harmful in some cases, *e.g.* table salt. Both desiccation and deliquescence can usually be prevented by excluding air and moisture.

## CHAPTER III

### THE NATURE OF MATTER

CHEMICALLY substances are regarded as mixtures, compounds, or elements, and in arriving at an understanding as to what the chemist means when he uses these terms we must glance at the prevailing ideas as to the nature of matter. In a sense the subject is philosophical but, leaving metaphysics out of account, we will assume that matter does in fact exist apart from the mind which observes it.

**ATOMS AND MOLECULES.**—All matter is supposed to be composed of very minute particles, perhaps of one stuff, which are in a state of violent motion. These tiny portions of matter collect in aggregates of definite construction called atoms. There are a certain number of ways in which these particles of the primal stuff can be built up together and various numbers of them can be used, and the units constructed of them are of fixed patterns. Thus, there are less than 100 known products of this aggregation, although each of these products occurs myriads of times. We thus have myriads of atoms of comparatively few different types. These atoms, however, cannot exist by themselves as such, for immediately an atom finds itself to be a free atom it becomes part of a structure which is sometimes a molecule and sometimes an "ion." The molecule is at last a complete unit capable of independent existence, and were it possible so to cut a substance as to get infinitesimal pieces the smallest piece we could get which would remain just as it was cut would be a molecule.

**MIXTURES, ELEMENTS OR COMPOUNDS.**—Now, substances can consist of different kinds of molecules, when they are called mixtures, or all of the same kind of molecule, when they are either elements or compounds. If the atoms making up the molecule are all the same the substance is an "element," but if the atoms are of different kinds then the substance is a "compound."

Gold, iron, sulphur, and oxygen are elements ; water, iron rust, Epsom salts and sugar are compounds ; whilst air, coal-gas and soil



are mixtures. The elements are usually divided into two classes, the metals and the non-metals. The metals are usually bright in appearance, and solid at the ordinary temperature (except mercury). If one part of a metal is heated the other part of it soon gets hot, and if one part be electrified the whole becomes electrified, *i.e.* metals are good conductors of heat and electricity. The compounds metals make with oxygen do not give acids with water. The non-metals are some liquid, some solid, and some gaseous under ordinary conditions; they are not usually bright in appearance, they are poor conductors of heat and electricity, and their compounds with oxygen, *i.e.* oxides, when combined with water are usually acids.

An atom of an element is denoted by a letter or letters in a sort of chemical shorthand, and a molecule by the letters denoting the elements used in making it up.

Thus O is an atom of oxygen.

O<sub>2</sub> or 2 atoms of oxygen united together is a molecule of oxygen, and H<sub>2</sub>O or two atoms of hydrogen united with one of oxygen is the recognized chemical contraction for a molecule of water.

## SECTION II—MINERAL PRODUCTS OF USE IN TRADE

### CHAPTER IV

#### THE PRECIOUS METALS

**GOLD.**—The use of metals and ideas as to their value take us back to remote antiquity, and even in the stone age metals seem to have been prized for their ornamental value. Thus in ancient Egypt flint knives have been found fitted with gold handles. Of all the metals gold seems the earliest to have attracted attention, although it is quite probable that meteoric iron would have been known as soon as there were men to know it. Gold always appears to have been specially valuable, and as early as 3600 B.C. its value compared with that of silver was fixed by law in Egypt. A naturally occurring alloy of gold and silver, known as electrum, was used as the material for coins in Lydia as early as 700 B.C., and of course practically all through the Old Testament a knowledge of the relative values of gold and silver is regarded as fixed and presupposed.

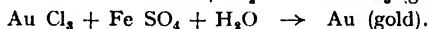
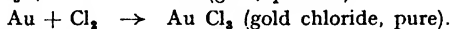
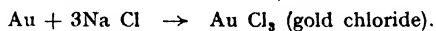
**Occurrence.**—Gold usually occurs as gold and not in chemical combination with other elements, although it is almost always mixed with other substances, chiefly silver. It is very widely distributed in nature and is probably contained in most fire-formed or igneous rocks, although of course only in very minute quantities. It is present in tiny particles, often imperceptible to the eye, in quartz. It occurs in equally small particles in quartz conglomerate, *e.g.* the Rand. A conglomerate is a rock formed from coarse particles, such as gravel, cemented together, and when such quartz or conglomerate is broken up and the resulting sand-like substance carried away by streams, the heavy gold is amongst the first substances to be deposited when the water is checked, as it does immediately below a fall or when it spreads out in lake-like floods. Such gold-containing debris are called "placer deposits," and are the usual material for small scale mining. The only important gold compounds found naturally are the tellurides, especially Petzite

(Ag, Au)<sub>2</sub>Te, a mixed telluride of silver and gold ; Sylvanite Au Ag Te<sub>4</sub>, and Calaverite Au Te<sub>2</sub>.

Most gold is contained in quartz, *e.g.* from California and most other U.S.A. regions. The most productive region in the world, *i.e.* the Rand, contains conglomerate ; most Yukon gold comes from placer deposits, and the gold of Western Australia (Kalgoorlie) and Transylvania is in the form of telluride.

**Extraction.**—The gold in placer deposits can be obtained by continually washing the loosened soil in pans whereby the heavy gold collects at the bottom and can be dissolved in mercury. The amalgam of mercury and gold so formed is squeezed in chamois leather, and the mercury passes through, leaving the gold behind. This method, however, would never pay in the case of quartz-contained gold where, as in the case of the Rand reefs, there is only .001 per cent of gold, or about twenty-four shillings' worth,<sup>1</sup> in a ton, *i.e.* the gold in a ton of quartz is only worth about half the value of a ton of coal in London to-day.

Such ore is first coarsely broken and then reduced to the finest powder in stamps, which are large mechanical pestles and mortars working, as a rule, five together in a battery. The powder in the mortar of the stamp is washed so as to take off the lighter material, leaving the heavier part containing the gold behind. The gold-containing portions can be further "concentrated" by shaking on a rubber band, or in a drum, or by some other means whereby the lighter and worthless material can be removed. This concentrated powder, or rather pulp, can be roasted if it contain sulphides (pyrites), then roasted with salt to convert the gold into impure gold chloride. The temperature is raised and the gold chloride is reconverted into finely divided gold (black in colour). This is put into vats, moistened with water, and chlorine gas led in. The gold is converted into soluble gold chloride, which solution can be strained off and the gold precipitated by the addition of ferrous sulphate (green vitriol) solution.



This method, called the "chlorination process," is now, however,

<sup>1</sup> *i.e.* when gold was £3 17s. 9d. per oz.

not much practised, the "cyanide process" being the one adopted on the Rand and in almost all cases where the gold is finely divided and small in amount.

The pulp of gold ore, or slime, as it is called, is treated for about twenty-four hours with a dilute solution of sodium cyanide (sometimes potassium cyanide) whereby the gold dissolves, forming sodium aurocyanide. The most modern tendency is for the whole



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*Messrs. Lees and Sanders.*

CUPELLATION FURNACE

powdered ore to be treated in this way, and not the "tailing" or remains after amalgamation or chlorination, as used to be done. The slime is agitated with the very dilute cyanide solution by means of compressed air and all the gold, and incidentally silver, dissolve out. The solution of  $\text{Na Au C}_2\text{N}_2$ , or sodium aurocyanide, is then treated with metallic zinc, which precipitates the gold and silver, whilst the zinc passes into solution, or else it is electrolyzed. When an electric current is passed through a melted compound of a metal, or through a solution of a compound of a metal the metal is usually thrown out of solution at what is called the cathode. In the present case an iron anode and a lead cathode are used and the gold and

silver are deposited on the lead plate. The lead, gold, silver mass is then cupelled, *i.e.* it is heated in a shallow porous crucible with sodium carbonate when the molten lead passes into the crucible ; most other metals form slag and can be taken off and the gold and silver remain. The gold and silver are separated by boiling up with sulphuric acid, when silver sulphate,  $\text{Ag}_2\text{SO}_4$ , is formed and metallic gold remains. In order to perform this stage in the refining there must be at least three times as much silver as gold present, and if, as is usual, this is not the case, silver is added to make up the amount. In America the refining is done electrolytically. In most cases the gold is not refined at the mines but by bullion refiners in London, etc.

Telluride ores must first be roasted to get rid of the tellurium.

**Properties of Gold.**—It is a bright yellow, soft metal (hardness = 2.5 – 3, of very high density = 19.3). It can be drawn out into very fine wire, *i.e.* it is very ductile and can be hammered out into extraordinarily thin sheets ( $\frac{1}{100000}$  of an inch thick), which means to say that it is exceedingly malleable. It is not tarnished by air, *i.e.* it is not oxidized or acted upon by sulphur and is unattacked by acids or alkalis, although it is easily attacked by molten metals, *e.g.* mercury. It dissolves quite easily in a mixture of nitric and hydrochloric acids (*aqua regia*) to form a solution of gold chloride. It is a very good conductor of heat and electricity.

**Uses of Gold.**—The chief use of gold is for money, and countries with a gold currency consume an enormous quantity in this way. There is no country which uses 100 per cent gold for this purpose, the Austrian ducat with 98.6 per cent being the nearest approximation, and this is not in circulation. About 90 per cent gold and the remainder mainly copper, is the usual. British gold is 91.6 per cent. There is considerable advantage in using a copper gold alloy for coinage, the chief being that such alloys melt at a lower temperature than gold and are therefore more easily worked. It should also be noted that at high temperatures gold is appreciably volatile, *i.e.* it evaporates, and since the loss increases with the temperature it is very desirable to work the gold at as low a temperature as possible. Quite a large amount of gold is obtained from the flues at the Mint each year. Another advantage of

copper alloy over pure gold for coinage is that such alloys are much harder than gold and therefore wear longer. In Britain the actual operation of coining is a stamping process, both sides of the coin, and the milling, being struck at once. The coins are passed straight from the stamp to an automatic balance which rejects all coins but those of legal weight.

Gold is also used in the arts, in photography, for jewellery, in dentistry and in chemical plant. In all these cases its use is chiefly determined by its chemical inertness, whereby it keeps its colour, does not produce unpleasant compounds in the mouth, etc.

Gold leaf is produced by rolling gold until it is about  $\frac{1}{8}$  in. thick, then placing these thin sheets between vellum and beating with a 16-lb. hammer, and subsequently trimming to size, placing between gold beaters, skin and beating until from  $\frac{1}{100000}$  to  $\frac{1}{300000}$  of an inch thick.

**Tests for Gold.**—It will not dissolve in most acids, but it will dissolve in a mixture of nitric and hydrochloric acids, forming a solution of gold chloride. It is, however, best assayed quantitatively by weighing the specimen, cupelling with lead and a flux, removing the slag, which contains copper, etc., compounds, and which floats on the top, boiling the metallic lead with nitric acid to remove silver and weighing the gold which is left.

**The Price of Gold.**—The price of gold has been fixed at £3 17s. 9d. an ounce, although in 1920 it was worth about £5 17s. an ounce. In normal times the quantity of gold in London is controlled by the Bank Rate, which is fixed by the Directors of the Bank of England. If London is short of gold they raise the rate of interest and as soon as the increased interest on a golden sovereign brings the excess to  $\cdot 7$ d. more than that in Paris, for example, it pays to export gold from Paris to London, for it used to cost  $\cdot 7$ d. to insure and send one sovereign from Paris to London. Contrariwise, when London has too much gold the Bank Rate is lower, and as soon as it pays to export gold from London to some other centre this is done. Gold is, of course, the standard for British and U.S.A. coinage, and for a great many other countries as well, although the fact that it is the standard does not necessarily mean that it is in ordinary circulation.

**PLATINUM.**—Platinum is a metal of higher value than gold. So far as is known it was first noticed in Colombia and was there given the name platina (plata = silver) because of its resemblance to silver.

**Occurrence.**—Platinum is almost always found in the metallic state in company with varying quantities of iron, iridium, osmium, palladium, etc. The only compound of platinum found naturally is sperrylite,  $\text{Pt As}_2$ .

Platinum is very widely distributed, being present in many of the older rocks, but in such small quantity that, in spite of the very high price of platinum, no rock is as yet worked as a platinum ore. It is only in the naturally-washed deposits of the detritus from such rocks that the heavy platinum which collects in them can be commercially worked.

The chief placer deposits of platinum are in the Ural mountains, mainly on the eastern side (Nizhni, Tagdsk, Bogoslowsk, etc.), and the only other important area is in Colombia (Choco and Barbarcoas).

Platinum, however, is sometimes present in placer deposits with gold (Oregon, U.S.A.), and it may pay to separate the platinum dissolved in the gold. This is done by the U.S.A. Government, and it is probable that the chief increase in supply of platinum will be by the development of such processes. Some is similarly obtained from the nickel matte of Sudbury, Ontario.

**Extraction.**—The platinum deposits are dredged or dug out (usually the former) and the lighter matter washed away. The metallic residue is then either cupelled with lead, which dissolves out the platinum, iridium, etc., or else, more frequently, treated with *aqua regia*, which dissolves the metals to form chlorides.

The palladium is first removed and then the platinum is precipitated as ammonium platino chloride or ammonium chloroplatinate (two names for the same substance). The chloroplatinate is then heated and metallic platinum is left in just the condition for easy working. Commercial platinum always contains iridium (about 2 per cent), but this is an advantage as the alloy is much harder than pure platinum.

**Properties of Platinum.**—Platinum is a silver-coloured, hard metal (hardness = 4–4.5) of very high specific gravity = 21.5. It is very malleable and ductile. It remains solid until the temperature

of  $1,780^{\circ}\text{C.}$  is reached but can be welded at a red heat. It has a coefficient of expansion almost exactly the same as that of glass, and joints can therefore be made between glass and platinum.

It is unacted upon by any pure acid, although it dissolves in *aqua regia*, but is very easily attacked by molten metals, especially lead. It does not conduct electricity well. It is entirely unacted upon by the air. It can be obtained in a spongy condition by heating ammonium chloroplatinate, and in a very finely divided form indeed (platinum black) by boiling platinic chloride with salt and sugar and in other ways.

**Uses of Platinum.**—The possible uses of platinum are very greatly curtailed by its extreme rareness. If it were as common as iron it would be of much more importance than that metal. As it is its use is confined to those cases where its cost can be afforded, and in cases where it is employed it is often indispensable. Indeed, it is so badly needed in certain processes where no substitute will avail that its use should be limited to such cases until more supplies of the metal are available.

The illegitimate uses of platinum, as we may call them, include dentistry, jewellery and photography, and in all these cases gold is a thoroughly efficient substitute. Its legitimate uses include sulphuric acid distillation plants, hydrofluoric acid plants, crucibles, etc., for chemical analyses, etc., as barium platinocyanide on screens to convert the X-rays into visible rays, and in pyrometers. These latter are of two kinds: in one, a platinum spiral is heated, and, since the resistance of platinum to electricity varies with the temperature and since platinum can be heated to very high temperatures without melting or oxidizing, high temperatures can be measured accurately which are quite beyond the range of ordinary thermometers. In the other pattern pyrometer high temperatures are measured by measuring the current formed by heating a joint made of platinum and platinum-iridium bars.

Platinum is used in electrical instruments and in electrochemistry, where it is essential that the electrode should not dissolve. Platinum black is used in the contact process for preparing sulphuric acid.



**SILVER.**—Silver, like gold, has been known from the very earliest times. Up to comparatively modern times it was scarce and consequently of high value, and it was not until the Spaniards brought the products of the Potosi ores of Peru (now Bolivia) to Europe that the value of silver fell to anything like what it is at present.

The war has seen a great appreciation in the price of silver in Britain, but it is quite likely due to the fact that the silver trade of the British Empire is in very few hands and with foreign competition the price will probably fall again. In certain countries silver is the standard of currency.

**Occurrence.**—Silver is sometimes found in the metallic state and in certain cases along with gold or copper. The chief ores of silver nearly all contain silver sulphide (silver glance,  $\text{Ag}_2\text{S}$ ) usually mixed with copper, antimony, arsenic, etc., sulphides. Horn silver (silver chloride,  $\text{Ag Cl}$ ) furnishes a fair quantity of silver, and since galena (lead sulphide,  $\text{PbS}$ ) and other ores of lead practically always contain silver, the working of lead ores gives large quantities of silver. Copper ores (pyrites) also give silver. The chief supplies of silver come from Mexico, U.S.A., Canada, Peru, Bolivia, Australia, Germany, Spain, etc.

**Extraction.**—Silver is worked in many districts and centres, sometimes on a very small scale and under difficult conditions, the result being that there is no standard method of extracting silver and many different processes are in operation.

(1) **AMALGAMATION PROCESSES.**—These depend on the fact that mercury displaces silver from combination and that an excess of mercury will dissolve the silver so liberated.

(a) *The Patio process* consisted in grinding the silver ore, tramping it up with salt, by means of mules, in a smooth courtyard (*patio*), adding mercury and copper and iron sulphates and moistening. This was left from two to four weeks, when the amalgam was collected, strained and heated in a retort. The mercury was collected under water and the crude silver left sold to the refiners.

This method, which was in use for 300 years, is now practically obsolete.

(b) *Pan-amalgamation process.*—In this process the ore is ground to slime and mercury added in the same vessel with traces of salt

and copper sulphate. The pan is heated with steam. At the end of the operation it is filled up with water and the heavy mercury, containing the silver, is drawn off at the bottom, strained through canvas, and the mercury distilled off as in the *patio* process.

The chemistry of both of these processes is doubtful, but it is probable that copper and iron chlorides are first formed which decompose the silver sulphide.

(2) LIXIVIATIVE PROCESSES.—The ores may be roasted with salt and the resulting silver chloride extracted with sodium thiosulphate (hypo) (Percy and Pateras process), or with brine (Augustin's process), and the silver precipitated, as sulphide, and then heated to form the metal, or else by copper.

The chief solution method is the cyanide process, which is somewhat similar to that used for gold except that the silver is in combination whilst the gold is in the metallic state. The silver ore is stamped to a very fine powder with weak sodium cyanide solution. The silver sulphide is converted into sodium silver cyanide  $[\text{Na Ag}(\text{CN})_2]$ . The solution is aerated and stirred by having compressed air blown into it all the time. This is necessary because along with sodium silver cyanide, sodium sulphide is produced which stops the reaction, but air oxidizes the sodium sulphide to sodium thiosulphate and the reaction can proceed.

The solution is drawn off and metallic zinc added which, on the formation of a zinc-silver couple precipitates the silver very rapidly.

The precipitated silver is pressed into blocks and smelted with nitre.

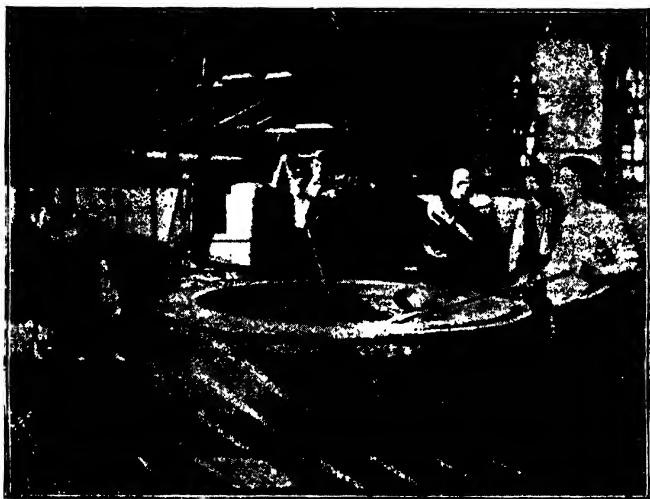
(3) SMELTING PROCESSES.—The ore is mixed with coke and limestone and heated in a blast furnace, the molten slag is drawn off at the top, and the silver lead is run out at the bottom. The lead is then desilvered.

(4) ELECTROLYTIC PROCESS.—Silver is separated from argentiferous copper by electrolyzing between a silver-copper anode and a pure silver cathode with an electrolyte of copper and silver nitrates. The silver is deposited on the cathode, any gold accumulates below the cathode, and copper remains in solution provided the proper current density be maintained.

**Desilverization of Lead.**—The silver lead is melted and molten zinc stirred in (about 1 per cent weight of silver lead); the zinc

forms a compound ( $\text{Ag}_2\text{Zn}_5$ ) with the silver, which floats on the molten lead and can be skimmed off. What lead is present in the silver zinc is removed by heating the skimmings on an inclined plate until the lead, but not the silver zinc, melts and flows away. The silver zinc is then distilled in a retort when the zinc passes over and the silver, with any gold, is left behind.

The silver can then be purified from gold by cupellation.



DESILVERIZATION OF LEAD

**Properties.**—Silver is a white metal of lustrous appearance. Only gold is more malleable and ductile than silver, which can be obtained only .00001 in. thick. It takes a pull of 17.27 tons to break a square inch section of it. When worked it becomes hard but can be softened by heating to  $200^{\circ}\text{C}$ . It has a specific gravity of 10.5, and whilst harder than gold is softer than copper.

It is the most perfect known conductor of heat and electricity.

It melts at  $961^{\circ}\text{C}$ . but is difficult to cast because it solidifies with airholes. When molten it will absorb twenty-two times its

own volume of oxygen, but it gives most of this out again on cooling. This produces an ebullition called sprouting. This "sprouting" can be avoided, however, by introducing some easily oxidizable metal which will combine with the oxygen, or if the silver be cooled very slowly it will not "sprout."

Silver is not attacked by oxygen but is very readily blackened by sulphur or sulphuretted hydrogen with the formation of silver sulphide,  $\text{Ag}_2\text{S}$ .

**Uses of Silver.**—Silver is used in the arts and in jewellery. It is used in scientific apparatus because of its high conductance of heat and electricity. It is not acted upon by alkalies and is therefore used for making vessels to contain them. Silver usually contains copper, and when heated in air goes black on the surface due to the formation of copper oxide, which can be removed by treatment with sulphuric acid. The silver on the surface is then pure and articles so treated are said to be of "frosted silver." If silver be dipped in a solution of sodium sulphide it becomes coated with a black layer of silver sulphide. This is called oxidizing, and the articles are said to be of oxidized silver. Silver is used very largely in coins usually alloyed with copper to harden it. British silver coins contain 7.5 per cent copper and 92.5 per cent silver, and a mixture of these proportions is called, by law, sterling silver. This rule is temporarily in abeyance, and a much poorer silver alloy containing nickel is at present in use.

**QUICKSILVER OR MERCURY.**—Mercury is the only liquid metal and as such has been of great interest throughout early and mediaeval scientific history, and as early as 300 B.C. its properties and preparation were described (Theophrastus). Its name is derived from its volatility or "quickness," wherein it was supposed to resemble Mercury, the Messenger of the Gods.

**Occurrence.**—Mercury occurs in very small quantities as the metal, but its chief, almost its only, ore is the sulphide or cinnabar. This is found in Spain (Ciudad Real, Oviedo, and Almaden), Carniola (Idria), Texas, California, Russia, Mexico, Italy, Bavaria, Peru, Japan, and China.

**Extraction.**—The extraction of mercury is quite simple and consists of roasting the ore, whereby the sulphide ( $\text{HgS}$ ) is converted into the metal, or else by heating the ore with lime. The mercury

vapour is collected and condensed in large chambers or in pear-shaped vessels (*aludels*). It can then be filtered through wash leather and, if necessary, re-distilled. It is sent on to the market crude, in jars (flasks) which hold about 75 lb. each (76½ lb.).

**Properties.**—Mercury is a bright white silvery liquid melting at  $-40^{\circ}\text{C}$ . and boiling at the comparatively low temperature of  $358^{\circ}\text{C}$ . It has a density of 13.6. It is a good conductor of heat and electricity and expands very regularly. It is almost unacted upon by the air. Most metals dissolve in mercury and the resulting amalgams easily furnish the two metals again. Mercury furnishes two series of salts, mercurous (where the mercury is monovalent) and mercuric (where it is divalent).

**Uses of Mercury.**—Mercury is used as a backing for mirrors. The fact that it dissolves metals finds application in the extraction of gold and silver (*q.v.*), whilst some of the lesser known amalgams are of great laboratory importance (*e.g.* sodium amalgam). Its regular expansion and good conductance of heat make it suitable for use in thermometers, whilst its great weight makes it possible to have a direct measure barometer of reasonable length. The metal itself is used in medicine as a purge (blue pill). Some of its compounds are of great value medicinally. They are all poisonous and some of them are very powerful antiseptics. A 1-in-1,000 solution of mercuric chloride is sufficient to destroy any bacterial life. Mercury compounds are used in ointment form to kill parasites on the human body. For many centuries it has been known that mercury (particularly mercurous iodide) is a specific for syphilis, and up to very recently it was practically the only known cure for that complaint. It is a cumulative poison and even small doses taken continuously produce noxious effects.

**RADIUM.**—In addition to the foregoing there are many other rare and sometimes expensive metals of modern importance, although space will not permit of anything like a full treatment of them.

Radium is one of the most interesting. It is present in many minerals and particularly in the pitch-blende (uranium oxide,  $\text{U}_3\text{O}_8$ ) of Joachimstal. Although an element, it seems to be produced by the decomposition of uranium, which is another element.

There is no known means of expediting that change and radium remains very rare. The metal itself decomposes, giving rise to other elements of a transitory nature, to helium (a gas) and to various rays. And it is these rays which are of commercial importance, for they have a pronounced effect on certain malignant growths. Radium is not only very expensive but it is very dangerous to carry about, but, fortunately, Radium Emanation, the first decomposition product of radium, is a heavy gas and when enclosed in a metal tube it is quite safe to transport. The emanation is collected in little capillary tubes and sent out to the various treatment centres. The capillary is strapped on to, or inserted in, the growth to be cured, is marvellously quick in action, and is quite painless; therefore no anaesthetic need be used. It removes birthmarks, etc. The cures in most cases are quite permanent and accompanied by no deleterious effect. Cancer is treated when surgical operation is impossible and is cured in a few hours, the typical cancer cells being entirely killed in that time but, unfortunately, in many cases the disease reappears in some other part of the body in about two years' time. Cases are known, however, when no further cancer has appeared to date (more than seven years).

**PALLADIUM AND IRIIDIUM.**—Palladium and iridium are metals of the platinum type. Both have commercial uses, iridium as an alloy for platinum whilst palladium is now being used in jewellery.

**THORIUM AND CERIUM.**—Thorium is an element somewhat similar in properties to radium. Its natural compounds are of very rare occurrence but of great value. It occurs in thorite (thorium silicate,  $\text{Th Si O}_4$ ), orangite, thorianite, and monazite sand. The chief supplies are from Norway, Ceylon, and Brazil.

From most of these ores both thorium and cerium salts can be obtained by dissolving in strong acids. A solution of the nitrates of thorium and cerium is then made and a woven stocking of ramie fibre or cotton immersed in it. This is dried and heated, first in a stove and then in the blow-pipe whereby the thorium and cerium nitrates become converted into thorium and cerium oxides, about 99 per cent thoria and 1 per cent ceria, and the fabric becomes a sort of skeleton of the mineral salts present in the raw material.

This is too fragile for transport and is therefore dipped in collodion and then sent on to the market as an incandescent gas mantle. When this is first lighted the collodion burns off, and when strongly heated the thoria and ceria become incandescent and emit a brilliant light. The ceria is necessary to ensure sufficient heating of the thoria (which conducts heat very badly).

## CHAPTER V

### COPPER, LEAD, TIN, ZINC, AND ALUMINIUM

**BASE METALS—COPPER.**—Copper has been known and used by man since prehistoric times and is now, after iron, the most used metal. It was used for implements contemporaneously with, and immediately following, stone. Indeed, the period after the New Stone Age is often called the Bronze or Copper Age. Its use was due partly to the fact that its properties were desirable, but partly also because it sometimes occurs naturally as copper. The Romans obtained it from Cyprus (Cyprium) and that is the origin of its name (Cyprium = Cuprum = Copper).

**Occurrence.**—Copper occurs naturally in large quantities in the Keweenaw Peninsula in the south of Lake Superior, as well as in other places. Its chief ores, however, are the sulphides, copper glance (chalcocite,  $\text{Cu}_2\text{S}$ ) and copper pyrites (chalcopyrite,  $\text{Cu Fe S}_2$ ). Other ores less frequently used are malachite, a basic copper carbonate [ $\text{Cu CO}_3 \cdot \text{Cu (OH)}_2$ ] and cuprite or ruby copper ore ( $\text{Cu}_2\text{O}$ ). The chief producing countries are U.S.A., Mexico, Chile, Spain, Australia, Russia, Germany, Canada, Rhodesia.

**Extraction.**—Non-sulphur—containing ores can be heated with coke in a blast furnace when impure copper is obtained in one operation, but in general the operations are much more complex. The first end aimed at is what might be termed a pure copper ore, that is to say, foreign substances such as iron, silica, etc., are removed, leaving a "matte" which contains a much higher percentage of copper than the original ore.

Most sulphur-copper ores contain too much sulphur for smelting purposes and it is necessary to remove the excess sulphur over and above enough to combine with all the copper to form  $\text{Cu}_2\text{S}$  and some iron into  $\text{FeS}$ . The sulphur is removed by "calcining," *i.e.* heating all or some of the ore to a temperature below the melting point.<sup>1</sup> The  $\text{SO}_2$  produced in this operation may be used in the manufacture of sulphuric acid. The calcined ore or mixture

<sup>1</sup>  $\text{CuFeS}_2 + \text{O}_2 \rightarrow \text{Cu}_2\text{O} + \text{Fe}_2\text{O}_3 + \text{SO}_2$ .



of ore and calcined ore containing the requisite percentage of sulphur is then smelted in one of two ways. If it contains much copper it is heated in a reverberatory furnace, *i.e.* the heat is drawn over the ore spread on a hearth, but if the ore be very crude it is treated in a blast furnace. The blast furnace itself is either of brick or of water-jacketed steel. The ore is mixed with coke and limestone in the furnace and cold air is blown in from pipes (*tuyères*) at low pressure. By this means the coke is converted to carbon monoxide ( $2C + O_2 = 2CO$ ) which reduces any cuprous oxide in the calcined ore to copper. This copper unites with any excess of sulphur in the ore, the whole of the copper becoming reduced to cuprous sulphide ( $Cu_2S$ ). In the meantime some of the iron has united with silica to form a slag whilst the rest has been converted to ferrous sulphide. At the temperature of the furnace, slag, cuprous sulphide and ferrous sulphide are all molten and can be drawn off through a spout into a trough. The mixture of cuprous and ferrous sulphides (*matte*) is much heavier than the slag which floats on the top and can be poured off, whilst the *matte* is let out at the bottom. Certain ores of the right composition can be made into *matte* in one operation (*pyritic smelting*).

The *matte* has now to be converted into very impure copper called "blister copper." The molten *matte* is run into a "converter," *i.e.* a cylindrical-bodied, conical-ended steel vessel capable of tilting. It is lined with silicious earth bound together with clay. Air can be blown in at the bottom. The converter was invented by Sir Henry Bessemer for converting cast iron into steel and the operation is called "Bessemerizing."

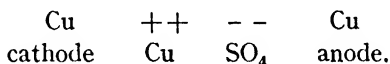
The oxygen in the air which is blown into the molten *matte* *first of all attacks the iron sulphide*, converting it into iron oxide and the sulphur into sulphur dioxide. The iron oxide immediately unites with the silicious lining of the converter, forming iron silicate. In due course all the iron and practically none of the copper sulphide has been changed, and the molten slag containing all the iron is run off by tilting the converter. The oxidation has by this time greatly increased the temperature, and as soon as the converter is righted and more air blown in some cuprous sulphide is oxidized to cuprous oxide. This attacks unchanged cuprous sulphide, forming metallic copper. When all the cuprous sulphide is

converted into copper (this is known by the appearance of the flame at the mouth of the converter) the converter is tilted and first slag is skimmed off and then the copper run out into moulds. The molten copper contains dissolved sulphur dioxide, and as it cools this is given off, making the bubbles which give the name of blister copper to the product of this operation.

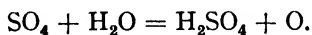
The blister copper is next spread on the hearth of a reverberatory furnace and melted. It contains dissolved cuprous oxide, and this is reduced to copper by pushing poles of green wood into the molten copper. The distillation products of the wood unite with the oxygen in the cuprous oxide. The copper can then be ladled out into moulds.

Ores containing small quantities of copper which are worked for other purposes, *e.g.* iron pyrites burned in the manufacture of sulphuric acid, are sometimes subsequently treated for copper. The residues are roasted with salt in air, the copper is converted into copper chloride ( $\text{Cu Cl}_2$ ), and any gold and silver are also changed into chlorides. The mixture is treated with water which dissolves out the chlorides, the silver and gold are removed and the copper precipitated with scrap iron ( $\text{Cu Cl}_2 + \text{Fe} = \text{Fe Cl}_2 + \text{Cu}$ ). The copper is then treated in a reverberatory furnace similarly to blister copper.

If the copper be required absolutely pure, as for instance if it be required for electrical purposes, it must be dissolved and electrolyzed out of solution. The copper to be purified is made the anode with a cathode of pure copper. The bath consists of acid copper sulphate solution which is ionised thus—

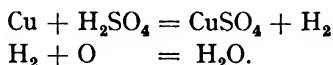


When the current is passed the copper ions travel to the cathode, and when they reach it give up their charge, and the copper atoms are electroplated on to the copper sheet. The  $\text{SO}_4$  ions give up their charge at the anode, attack the water forming sulphuric acid and oxygen.



The sulphuric acid dissolves more copper from the anode to form

copper sulphate, and the hydrogen so liberated unites with the oxygen above to form water.



The concentration of the bath is thus kept constant and any impurities in the copper, *e.g.* arsenic, drop to the bottom. Copper purified in this way is marketed as electrolytic copper.

**Properties.**—Pure copper is lustrous and of a pink colour, although when kept in the air it tarnishes and becomes “copper-coloured.” It has a specific gravity of 8.9, and is harder than silver. It melts at 1082–4° C., and when near its melting point is so brittle as to be powdered easily. It is a splendid conductor of heat and, after silver, is about the best conductor of electricity. It is very easily the best conductor available for commercial use. Its conductance is enormously diminished by even small quantities of impurities, *e.g.* arsenic, hence the necessity of electrolytic copper for electrical purposes. Copper has a low specific heat, .094.

Copper is very tough, malleable, and can easily be drawn into wire. Besides the tarnish above-mentioned, moist air, which also contains carbon dioxide, acts on copper with the formation of a green basic carbonate “verdigris,” whilst sulphur-containing air gives green-blue basic sulphates. On heating in air copper becomes coated with mixed cuprous (red) and cupric (black) oxides. Copper is insoluble in cold sulphuric or hydrochloric acids but dissolves on heating. Nitric acid easily dissolves copper. Ammonia and water attack copper with the formation of a blue solution. The salts of copper are nearly all poisonous. Molten copper dissolves many other metals, forming alloys which are in many cases of great importance.

**Uses.**—Copper is used for electric leads, cables, etc., its only possible rival in this connection at the present time being aluminium. It is usually used for the tubes in boilers and for many domestic implements which require heating *e.g.* kettles. It should not, however, be used in this way unless the inside is tinned, since copper compounds may be formed and are poisonous.

Ships are cased in copper and where much contact with water is probable copper nails and rivets are used in preference to iron.

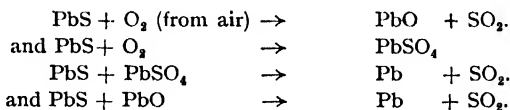
Printing reproduction processes are often carried out with copper plates.\* A large amount of copper is used in alloys, *e.g.* coins, brass, etc., and in particular it hardens gold and silver,

Of the copper compounds the one most frequently used is the sulphate, blue vitriol or blue stone, which is largely used in agriculture as a germ and blight poison, *e.g.* for spraying for potato-disease and the phylloxera (Bordeaux mixture).

**LEAD.**—Lead was known to the ancient Egyptians and it is referred to in the Old Testament many times. It was used by the Romans for making water pipes, and some of its compounds were used by them in paints and cosmetics.

**Occurrence.**—Lead ores are obtained in the U.S.A., Mexico, Spain, S. America, New South Wales, Germany, United Kingdom, etc. Although metallic lead and many ores of lead are found in nature the lead of commerce is derived almost exclusively from one of them, *e.g.* galena (lead sulphide,  $\text{PbS}$ ). Cerussite (lead carbonate,  $\text{PbCO}_3$ ) and anglesite ( $\text{PbSO}_4$ ) are occasionally worked for lead.

**Extraction.**—Galena containing a high percentage of lead sulphide is usually heated on the hearth of a reverberatory furnace in a current of air. Some of the lead sulphide becomes converted into lead sulphate or lead oxide. The air supply is then cut off and the remaining lead sulphide reacts with the lead sulphate or oxide formed at first, liberating molten lead which flows into a hollow in the hearth of the furnace and can then be drawn off.



Low grade ores are usually heated in a small blast furnace with coke and a flux, *e.g.* limestone, whilst lead ores rich in valuable metals, *e.g.* silver, are heated with iron or iron oxide and coke in a blast furnace. The result is a matte containing, in addition to lead, say, copper, silver, and iron sulphides.

**Purification.**—The lead made by these impurities will contain, probably, two kinds of impurity, *viz.*, those which easily oxidize like copper, antimony, arsenic, etc., and silver, which does not easily oxidize. The first class of impurity is removed by heating the

crude lead in a reverberatory furnace and skimming off the oxides of the impurities which are formed and which float on the molten lead. Since the impurities make the lead hard this process is called softening the lead. The silver is obtained by Pattinson's or Parkes' process, usually the latter, by dissolving out in zinc. (See under SILVER, p. 21.)

**Properties of Lead.**—Lead is a blue-grey, and, when freshly cut, a lustrous, metal. It is very soft and has a specific gravity of 11·4 (rolled). It is not tenacious and therefore cannot be drawn into wire, neither can it be hammered into sheets, but it can be rolled into foil and pressed into wire or pipes. When divided lead, *e.g.* filings, is sufficiently strongly compressed (13 tons to the square inch) it becomes a solid mass again, whilst at 33 tons to the inch lead flows. This flowing under pressure is common to all metals, even steel becoming of the consistency of treacle when sufficiently compressed. Lead melts at 326–328° C.

In moist air lead readily oxidizes to lead suboxide ( $\text{Pb}_2\text{O}$ ) and this changes gradually to lead carbonate, but the thin film of carbonate thus formed protects the lead from further corrosion and lead articles will last for centuries. Water containing carbon dioxide but no calcium bicarbonate will dissolve lead, and therefore it is sometimes necessary to pass exceptionally pure water for domestic supply, *e.g.* that from Welsh lakes, through chalk. This then forms a layer of carbonate over the interior of the lead pipe and further action is prevented.

Lead is easily acted upon by nitric acid and some organic acids; therefore, since all lead compounds are poisonous, lead vessels must not be used for cooking utensils.

Molten lead readily dissolves many other metals.

**Uses of Lead.**—Lead is used in cases where an easily worked metal is necessary, since it melts at a low temperature and can readily be bent and shaped. Domestic metal joints and water connections are so frequently made of lead that the work is called "plumbing," *i.e.* lead-ing. It is used for water pipes and cisterns, and in the form of foil for containing tea. It has the highest density of any common metal and hence is used where weight is a necessity, *e.g.* for the keels of ships and for shot and bullets. When molten lead is dropped from a great height into water it assumes

a spherical shape and shot are made in this way (the lead is combined with 3 per cent of arsenic). Electric cables are usually lead covered and accumulator plates or grids are generally of lead filled in with lead oxide. The "chambers" in the chamber sulphuric acid process are made of lead, and leaden apparatus is used in much other chemical plant. Many of the solutions of other metals in lead are of great commercial importance, *e.g.* solder (about half lead and half tin), pewter (80 per cent tin, 20 per cent lead). Type metal (about 18 per cent antimony, 5 per cent tin, up to 80 per cent lead) and easily fusible metals used in bearings usually contain some lead.

Some of the compounds of lead are important. The chief of these is white lead (basic lead carbonate, mainly  $2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$ ), which forms the "body" in lead paints.

The manufacture of white lead in England is usually carried on as follows: In a brick chamber a floor of spent tan is made and on this many earthenware pots (1,000) of dilute acetic acid (2-3 per cent) are placed. Over the tops of the pots the space is filled in to a depth of a few inches with small grid-like castings of pure lead. A wooden floor is built over and on this is spread more tan, pots of acetic acid and lead, and so on until a stack about 20 ft. or so high is produced. Tan is spread over the top. The stack is closed in with wood and the tan ferments, generating heat which volatilizes the acetic acid, whilst carbon dioxide is also produced. The acetic acid, attacks the lead, forming lead acetate, which is decomposed into basic lead carbonate. After about three months the stack is opened, the white lead formed washed to take out any lead acetate and then milled to separate from unchanged lead. The white lead is then ground whilst wet into a very fine powder, which is gradually dried off and barrelled, or else ground up with about 8 per cent of boiled linseed oil to form a paint.

Other important lead compounds are litharge or massicot (lead monoxide,  $\text{PbO}$ ), which is formed when lead is gently heated in air. Litharge is used in making glass and earthenware glaze, and in the manufacture of other lead compounds.

Red lead or minium ( $\text{Pb}_3\text{O}_4$ ) is formed when massicot is further heated. The massicot is raked into furrows in ovens and heated until it is of the correct colour. Red lead is used in gas and steam joints, in accumulators, in the manufacture of glass, and in paints.

Lead acetate, or sugar of lead, is used in dyeing and printing cotton, in making chrome-yellow paint, and in medicine. Goulard's lotion is a solution of basic lead acetate.

All lead compounds are poisonous and workers in them are subject to a disease called lead poisoning, plumbism or Saturnism (Saturn is a slow-moving planet and lead was named after it by the alchemists). The disease is characterized by a blue line in the gums (lead sulphide), nervous prostration, fits, and finally paralysis. There is not much doubt that it is usually due to a lack of cleanliness on the part of the workmen.

**TIN.**—Tin is mentioned in the Old Testament and its alloy with copper, *i.e.* bronze, has been used from very early times. Many ancient bronze implements are still in existence. Tin formed one of the chief articles of trade of Britain even in pre-Christian times. It was obtained chiefly from Cornwall, the Scilly Isles, and, in addition, from Spain. So far as is known there was no naturally occurring tin in Syria, Greece, Rome, etc., and that is evidence of a very early trade with western and northern regions. The extraction of tin is described by Pliny, but some of the old references to tin seem to confuse it with lead.

**Occurrence.**—Tin is not at all widely distributed in Nature. The chief source is Malaysia, with the islands of Banka and Billiton. Bolivia is another important source, and further supplies come from Peru, Nigeria, the Transvaal, U.S.A., New South Wales, South Australia, England, Germany, Austria, China, Siberia, etc.

Tin chiefly occurs as tin stone or cassiterite (tin oxide,  $\text{SnO}_2$ ), although some tin pyrites (tin sulphide,  $\text{SnS}_2$ ) is also worked.

**Extraction.**—Tin stone is heavy and, by stamping the ore just sufficiently to break up the matrix and subsequently washing, ores containing less than 1 per cent of tin stone can be worked profitably. The concentrated ore is mixed with 15–20 per cent of powdered anthracite on the sloping hearth of a reverberatory furnace and heated. Some of the slag is raked off but the molten remainder is drawn off with the metallic tin. The tin is refined by just melting, when the pure tin, but not the impurities, can be drawn off. This is then, whilst still molten, treated with green wood (see COPPER) and the refined tin cast in ingots.

Tin made from pure ores, and of which only the upper layers

are taken on refining, is called "Refined Tin," other tin is known as "Block Tin." Grain tin is made by further purifying refined tin.

The London Metal Exchange classifies tin as—

(a) when not less than 99.75 per cent tin, and

(b) when from 99–99.75 per cent tin.

**Properties of Tin.**—Tin is a silver white metal which, when pure, casts into round cornered ingots. It melts at  $232^{\circ}$  C. and has a specific gravity of 7.3. It is softer than gold but harder than lead. It is ordinarily brittle, but at  $100^{\circ}$  C. can be rolled into foil or drawn into wire; at  $200^{\circ}$  C. it again becomes brittle. Tin, when continuously exposed to a low temperature, falls into a powder (grey tin), the maximum rate of change being at  $-50^{\circ}$  C. It is therefore not suitable for use in high latitudes. Tin is a good conductor of heat and electricity. It is not acted upon by air at the ordinary temperature and is not easily attacked by organic acids. It dissolves readily in mineral acids and in solutions of the alkalies.

**Uses of Tin.**—The chief use for tin is in plating iron or other metals in order to prevent corrosion. Domestic vessels can be tinned inside by first cleaning the vessel, then melting a mixture of tin and resin inside it and wiping the molten mixture over the interior surface and pouring off the excess of tin. This method is of great antiquity and was described by Pliny, and since 1 oz. of tin can be made to cover 200 sq. ft. of iron we are able to account for his remark that copper when tinned does not gain in weight.

Since the tin plating of iron, after being carried on in Saxony, was introduced at Pontypool in 1720, South Wales has become the tin-plating centre of the world.

Mild steel sheets, after special treatment and annealing, are placed in weak sulphuric acid to remove oxide and washed, first with sand and then with water. The cleaned sheets are greased with palm oil or tallow and put into a bath of molten tin which is covered with a layer of killed spirit. The imperfectly tinned plate is then again immersed in melted tin, brushed over to ensure an even coat, re-dipped to remove brush marks, and greased and rolled to produce a fine surface. A disadvantage of tin plate is that, since tin is more electro-negative than iron, when any of the tin wears away and some iron becomes exposed galvanic action is set up



and the iron, in consequence, rusts more quickly than if it had not been plated.

Tin foil is much used as a wrapping for foods, *e.g.* cream cheese, chocolate, etc., since tin is not attacked by organic acids. Pipes, pans, etc., used in food manufacture are also tinned for the same reason.

Tin forms an important constituent of many alloys, some of the most important being bronzes. There are many different bronzes, but they usually contain about 80–90 per cent copper and 10–20 per cent tin. Some of them contain a little zinc and/or lead. Solders contain up to 50 per cent of tin and most of the remainder is lead. White metal contains about 70 per cent tin with lead and zinc. Antifriction bearing metals always contain large quantities (from 18–95 per cent) of tin.

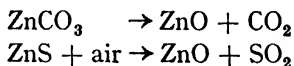
Tin salts are much used as mordants in the dyeing and calico printing industries.


**ZINC.**—Zinc bracelets have been found in the ruins of Cameros, which was destroyed in 500 B.C., and there are many mentions of brass, which contains zinc, in ancient writings. Brass, however, can be produced by using zinc ore and not metallic zinc. Paracelsus first recognized zinc to be a metal about A.D. 1500. At the time when the first zinc factory was started in England (at Bristol, 1743), most of the zinc used in this country was imported from China and India. Since brass has been made directly from its constituent metals there has been a great demand for zinc.

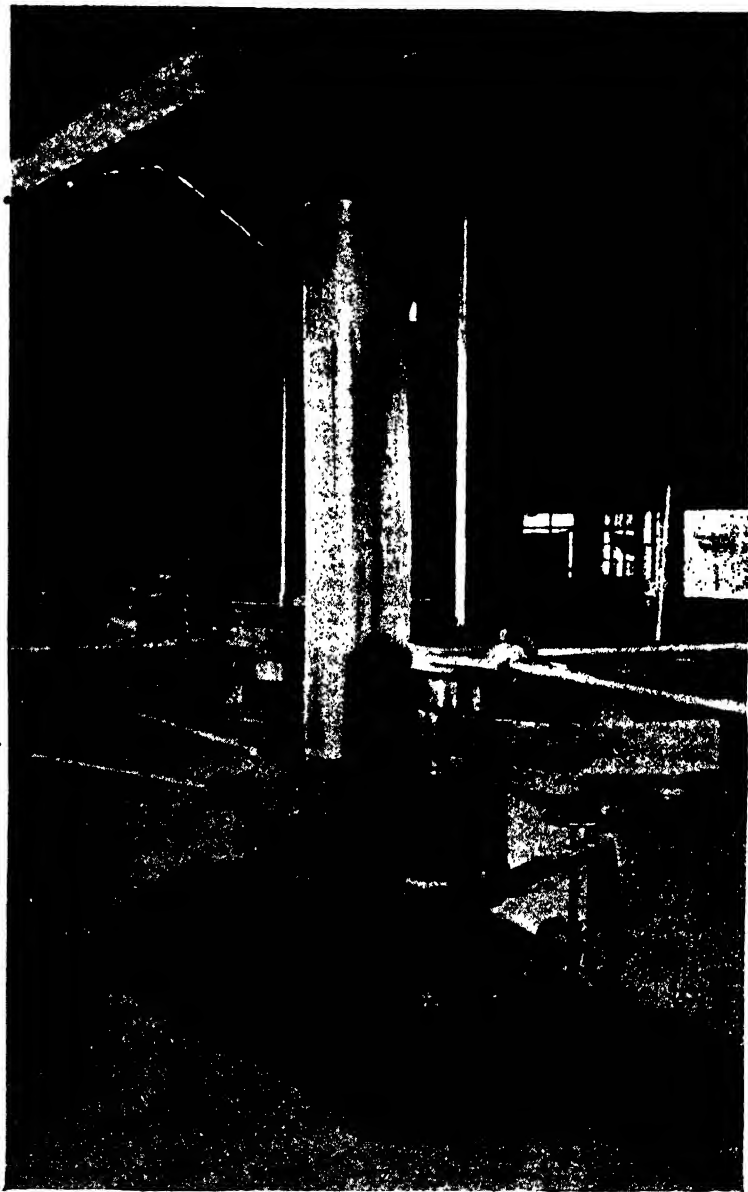
**Occurrence.**—Zinc has been found native in Victoria, but occurs almost exclusively in the combined state. The chief ores are the carbonate (calamine,  $\text{ZnCO}_3$ ), the sulphide (zinc blende, black jack,  $\text{ZnS}$ ), and the oxide (zincite, red zinc ore,  $\text{ZnO}$ ).

The chief countries producing zinc are Silesia (Konigschütte), Belgium (Moresnet), and U.S.A.

**Extraction.**—The ore is roasted whereby it is converted into oxide—



The oxide is then mixed with small coal or coke and heated to redness in tubular or  shaped fireclay retorts.



*By permission of*

*The Royal Society of Arts.*

**MACHINE-MADE ZINC RETORT**

The oxide is reduced to the metal



and at the temperature of the reaction the zinc volatilizes and distils over into iron receivers. The first portion of the distillate consists of a powder, "zinc dust," which is a mixture of zinc oxide and zinc, and which is separated from the remains of the distilled zinc. It has a commercial value, particularly in the dyeing industry, as a source of hydrogen. The bulk of the distillate collects as a liquid and is drawn off. The crude zinc, spelter, is purified from the carbon, lead, arsenic, etc., and cadmium, which it contains, by redistillation.

Zinc ores are now in certain cases smelted electrically.

**Properties of Zinc.**—Zinc is a bluish-white metal, brittle at ordinary temperatures but malleable and ductile from 100–150° C. Zinc which has been warm rolled at this temperature is not brittle at ordinary temperatures. Above 200° zinc can readily be powdered. Zinc has a specific gravity of about 7. It is harder than tin but softer than copper. Commercial zinc is never pure, but contains lead, iron, arsenic, etc. The lead is an improvement if the zinc is to be rolled but is undesirable if good brass is to be made. Zinc melts at 420° C. and at a temperature not much above that it burns forming zinc oxide called Philosophers' wool, because of its flocculent appearance. Pure zinc is not attacked by dry air, though moist air produces a slight tarnish. It readily dissolves in boiling alkali solutions but is not attacked by water at 100° C., nor does it easily dissolve in acids. Commercial zinc readily dissolves in acids as well as in alkalies. Super-heated water dissolves zinc and, probably, water containing minute quantities of certain impurities will attack zinc. Zinc vessels or pipes should not be used, therefore, to contain drinking water. This action of water on zinc is much more pronounced when copper is present in contact with the zinc, when galvanic action seems to hasten the decomposition. This was brought to the writer's notice during the late war when men had serious attacks of diarrhoea as a consequence of drinking tea made in a galvanized bath heated by steam through a copper pipe.

Zinc casts remarkably well, giving very sharp edges, and so is

used for art work. This property of zinc is conferred on certain of its alloys, *e.g.* "bronzes," which contain little copper. Zinc dissolves other metals to form important alloys, *e.g.* brass.

**Uses of Zinc.**—The chief uses of zinc are in alloys, particularly brass and for galvanizing.

Galvanizing consists in coating an iron sheet with a layer of zinc. Zinc is electro positive with respect to iron, and consequently when any part of the zinc is removed by wear the iron beneath it is not removed electrolytically, but is to a certain extent still protected. Galvanizing is carried out very similarly to tin plating. The annealed iron sheets are for a very short time pickled in hydrochloric acid to remove scale (iron oxide) and then coated with ammonium chloride to serve as a flux and immersed in a bath of molten zinc. These operations are sometimes carried on by machines in one process. Iron wire is galvanized by reeling it continuously first through the acid and then through the molten zinc. Galvanized articles may contain anything from 3 to 25 per cent of zinc. Corrugated iron is galvanized in flat sheets and then corrugated.

A big galvanizing firm will use thousands of tons of hydrochloric acid in a year and the disposal of the spent pickle is a very serious matter. It is an acid solution of ferrous chloride and would pollute any water system into which it was discharged. It is now usually converted into ferric oxide and sold to the manufacturers of wrought iron for use in the puddling process. Galvanizing is also carried out electrolytically. Zinc is also used for pipes, roof-covering, etc. Some zinc compounds are used medicinally, *e.g.* zinc ointment and zinc lotion. Zinc carbonate and zinc oxide are very largely used instead of white lead (which is poisonous) in paints.

**ALUMINIUM.**—Aluminium, although the most plentiful of all the metallic constituents of the earth's crust, was not known in the metallic state until the middle of last century, and it did not become a commercial article until about the year 1900, when the total output of the world was less than 6,000 tons. Its price has fallen meanwhile from £50 a lb. in 1855 to less than 8d. a lb. in 1913 and about 1s. 4d. a lb. at the present time.

**Occurrence.**—It is a constituent of clays, felspar, granite, etc. An important though rather rare compound is cryolite,  $\text{Na}_3\text{AlF}_6$ .

Its chief ore is bauxite, which is a name for various hydrated oxides.

Bauxite occurs in the Baux Hills near Arles, in S. France, in Northern Ireland and in Arkansas, Georgia and Alabama (U.S.A.).

**Extraction.**—Commercially, aluminium is always prepared electrolytically, and this has led to its being produced where there is great water power, *e.g.* the Niagara Falls, in Norway, and at Foyers and Kinlochleven in Scotland.

Bauxite, first purified by fusion with soda and subsequent precipitation with ammonia or carbon dioxide is dissolved in fused cryolite and electrolyzed in carbon or iron crucibles. The metal can be drawn off at the bottom (the Héroult Hall method). If a commercial method could be discovered for the separation of silica from clay aluminium would become very much cheaper.

**Properties.**—Aluminium is a white metal with a blue tinge. It can be highly polished, is rather soft and very light, having a specific gravity of 2.6–2.7. At temperatures of 100–150° C. it is ductile and highly malleable. It can be hot rolled. It is a very good conductor of heat and electricity. It is not easily acted upon by air or water, but when heated to a sufficient temperature, particularly if powdered, it burns in air with an enormous evolution of heat, forming the oxide. It melts at 657° C. and dissolves most other metals, forming alloys, some of which are very important.

**Uses.**—Aluminium is used as a material for saucepans and other domestic implements, and in many other cases where lightness is desirable, but for structural work, boat and aeroplane building, motor engines, etc., it has been superseded by some of its alloys such as duralumin and tensalum, many of which are tensilely stronger than steel. Although it has a considerably greater electric resistance than copper, yet since it is much lighter than that element it can and does compete with it for cables, leads, etc.

Aluminium powder mixed with iron oxide, or some other metallic oxide, burns very easily in air, and produces such a temperature—up to 3,500° C.—that iron is automatically welded. Tram lines, castings, etc., can be joined together in this way without removal from position. The mixture is known as thermite.

In future it is quite probable on account of the high cost of cabinet-makers' timber that aluminium and its alloys will be used

for furniture. Copper containing small quantities of aluminium is used as a substitute for gold in cheap jewellery.

Alloys of aluminium containing magnesium are in particular demand at the present time, as they are light, tenacious, and easily turned and worked.

**Compounds of Aluminium.**—Apart from alloys the best known compounds of aluminium in ordinary use are clay and alum. Clay is a complex silicate which, when moderately pure and free from iron, is as aluminium silicate known as kaolin or china clay. Alum is potassium aluminium sulphate, and is used as an astringent in medicine and as a mordant in dyeing.

Quite small percentages of aluminium in other metals prevent oxidation and consequently foundrymen use it, *e.g.* in iron to ensure good "blow"-less castings, and there are very many alloys of aluminium in common use. Aluminium bronze contains about 10 per cent aluminium and the rest copper, whilst there are a very large number of compounds of aluminium with magnesium, all of which are light, strong, and non-tarnishable.

## CHAPTER VI

### THE RARER COMMON METALS

**CADMIUM.**—Cadmium is present in small quantities, .1 to .5 per cent, in nearly all zinc ores.

**Extraction.**—No ore is worked exclusively for cadmium, it is a by-product in the preparation of zinc. When the zinc ores are reduced and the zinc begins to distil over, the first part of the distillate contains nearly all the cadmium (up to 6 per cent). This first fraction is then mixed with coal and redistilled at a low temperature, when crude cadmium comes over. Fractional distillation of the crude metal produces almost pure cadmium. Cadmium is also separated from zinc electrolytically.

**Properties.**—Cadmium is a lustrous white metal which will mark paper. It is more tenacious than tin but becomes brittle at 80° C. It melts at 322° C. and boils at approximately 778° C. Molten cadmium dissolves other metals, forming alloys.

**Uses.**—Cadmium is chiefly used in alloys. Generally speaking, cadmium alloys have low melting points and in particular the bismuth tin lead cadmium alloys have extraordinarily low melting points (65° C.) and are called, with certain other alloys, fusible metals.

Cadmium sulphide (cadmium yellow) is used very largely as a colour (oil and water) in calico printing and for dyeing soaps. Cadmium salicylate and iodide are used in medicine and the latter as well in photography. Cadmium sulphate is used in the Weston standard cell.

**BISMUTH.**—Bismuth and its compounds are very widely distributed in Nature. The metal is found Native with other metals in Saxony, Carinthia, New South Wales, South Australia (Adelaide), and Sweden (Fahlun). The sulphide and oxide are also obtained from most of the above places, and the oxide in particular in Bolivia. Bismuth carbonate (bismuthide) occurs in Mexico and North Carolina.

**Extraction.**—Bismuth ores are roasted to expel sulphur and then smelted with a suitable flux. The crude molten bismuth thus

obtained is allowed to flow on an inclined iron plate whereby much of the impurity remains on the plate.

The crude bismuth is first of all freed from such deleterious impurities as arsenic (As) and sulphur by fusion with nitre whereby these substances are oxidized away. The other impurities (mainly metallic) are removed individually by special means. Bismuth must often be obtained very pure since it is used in medicinal preparations.

**Properties of Bismuth.**—Bismuth is a rosy-tinged white metal of pronounced crystalline structure and is very brittle. It is a poor conductor of heat and electricity, in this way showing its relationship with the non-metals. Bismuth has a density of 9.8, and melts at 264° C. When bismuth has set after casting it expands. Bismuth is the most strongly diamagnetic substance known, *i.e.* when suspended between the poles of an electro-magnet it comes to rest at right angles to them. The lines of force travel across and not along it.

It is also the most strongly electro-negative of all the metals and is therefore used in constructing thermopiles.

Bismuth easily dissolves in nitric acid but only with difficulty in sulphuric and hydrochloric ; it reacts with steam.

**Uses of Bismuth.**—Bismuth is used in fusible alloys (v cadmium), and some of its alloys are largely used in electrolytic moulds.

Many of its compounds are used medicinally, *e.g.* the subnitrates, in ointment for open sores and as a cosmetic ; the sulphite, to arrest intestinal putrefaction and to expel worms ; but these have been largely superseded by the subsantonate of bismuth.

Bismuth carbonate is very largely used as a cure for indigestion and the oxychloride as a toilet powder.

Basic bismuth gallate is known as “dermatol” and the oxyiodo subgallate as “airol.” Basic bismuth dibromohydroxy naphthoate and thioform, or bismuth dithio salicylate, are all used as substitutes for iodoform. It is claimed that bismuth gauzes, *i.e.* dressings antisepticized with bismuth preparations, are inodorous and can be used longer than iodoform dressings.

Bismuth subnitrate is used in glazing porcelain.

The output of bismuth is controlled by a trade agreement, otherwise more could be produced than is required.



**ANTIMONY.**—Antimony more than any other element was regarded with awed mysticism and veneration by the 'mediaeval alchemists, and the obtaining of it from its ores was almost a religious rite. In an old book by Basil Valentine, a copy of which was in the possession of the late Sir William Ramsay, there is a picture entitled "The Triumphal Chariot of Antimony." In it is shown the emergence of antimony from its compounds and this seems to be regarded as almost akin to the passing of a soul into Paradise.

Antimony compounds have been used as "face paint," and particularly for the eyebrows throughout history, and it was probably one of these substances that was used by Jezebel, Aholah, and Aholibah.

**Occurrence.**—The metal is found native in Borneo but occurs usually as the sulphide  $\text{Sb}_2\text{S}_3$  (stibnite).

**Extraction.**—In practice only good grade stibnite is worked and such ores should contain at least 50 per cent of antimony. The ore is ground up with about 10 per cent of salt, and some scrap iron is added. The mixture is placed in plumbago crucibles (about twenty to a furnace) and heated. The iron reduces the stibnite to antimony, iron sulphide being formed which, with impurities, floats on the molten metal. The melt is then poured into moulds. Further meltings or refinings usually produce the pure metal, which can be recognized by its characteristic star-patterned surface and is therefore called star antimony.

**Properties.**—Antimony is a blue-white metal of crystalline structure and brittle. It has a specific gravity of 6.7, and is harder than zinc and gold but softer than silver. It is not a typical metal but approaches the non-metals in some of its properties. Thus it is a bad conductor of heat and electricity. It probably, like phosphorous, sulphur, etc., exhibits allotropism, that is to say, exists in more than one form, perhaps because the molecules in one form contain more atoms than in another. One of these forms explodes when scratched, but it always seems to contain chlorine, so that it is not certainly an allotrope.

Antimony melts at  $450^\circ \text{C.}$  in air and  $629^\circ \text{C.}$  in carbon monoxide. After melting antimony expands on solidification. Antimony is not tarnished by air at the ordinary temperature but burns when heated in air.

Sulphuric, hydrochloric, and nitric acids act with difficulty on antimony. The first two form sulphate (unstable) and chloride respectively, while the last gives oxides of antimony.

**Uses of Antimony.**—Virchow and Berthelot both instance cases of ancient ornaments consisting of pure antimony, but nowadays antimony is never employed in this way. It is either used to plate other metals or else, and more frequently, in alloy with them. Antimony expands on solidification and so do its alloys, and thus antimony-lead alloys when cast give very sharp impressions and are used (with a little tin) for type metal. Britannia metal also contains some antimony.

Many of the compounds of antimony are of value in commerce. The black native sulphide of antimony has been used in the East from time immemorial to darken eyebrows. The Arabs call it kohl, which become *alkol* and later *alcohol*. This last form was, in the Middle Ages, given to any finely powdered substance produced by certain processes. One of these processes was distillation, and in course of time the word "alcohol" became applied only to "spirits of wine" produced by distillation. It is now used for this substance, however produced.

Antimony sulphide is sometimes used in match-heads and percussion caps and for certain pyrotechnic effects. An oxysulphide is used in paint, whilst the brown colour of gun and rifle barrels is produced by treatment with antimony trichloride. Antimony compounds are violently poisonous, and one of them, potassium antimonyl tartrate (tartar emetic) is of medicinal value. In addition to being an emetic it greatly decreases the activity of the heart. This substance is also used in dyeing cotton.

Antimony is mostly produced in England. The world's output is above 3,000 tons yearly.

**ARSENIC.**—Arsenic is one of the metalloids, that is to say, it has some properties which resemble those of the metals and some which are akin to those of the non-metals. A compound of arsenic was known to Aristotle. The word itself means "potent". It is found in the elementary state, but more frequently combined, *e.g.* the oxide, arsenolite ( $\text{As}_2\text{O}_3$ ), the sulphide, realgar ( $\text{As}_2\text{S}_2$ ); and mispickel or arsenical pyrites ( $\text{AsFeS}$ ); kupfernickel ( $\text{NiAs}$ ), etc. It is present to some extent in almost all samples of pyrites and in zinc.

**Preparation of Arsenic.**—Either the native product is used or else arsenical pyrites is distilled, whereby the arsenic sublimes and can be collected. Arsenic is used in bronzing and also in making shot. Lead containing .1 per cent arsenic is much harder than when pure and, further, melts at a lower temperature and so more readily assumes a spherical shape before solidifying when dropped into cold water.

**Arsenious Oxide.**—The chief use of arsenic, however, is as the oxide. This is obtained as a by-product in the roasting of arsenical ores, by the burning of arsenic and by heating mispickel in air. The arsenical "soot" which results is purified by sublimation. It is used in sheep dip, as an insecticide and vermicide and as a preservative (for skins). Two important colours, Scheele's green ( $\text{CuHAsO}_3$ ) and Schweinfurt green, are made from it. The former used to be used in wall paper.

Arsenic compounds are used medicinally in cases of anaemia, malaria, neuralgia, etc. It is usually administered as Fowler's solution.

Quite recently it has come into great prominence in the treatment of syphilis. It is well known that arsenic compounds are poisonous as well to micro-organisms as to human life. Many harmful bacteria, etc., could be killed by arsenic if it were not that the dose would be dangerous to the life of the person acting as host.

Micro-organisms can absorb certain colours and exercise selection in so doing. For instance, some yellow dyes are absorbed by the spirilla of syphilis but not by the cells of the human body. It has been found possible to make a compound of arsenic with such a yellow dye, and this compound is also absorbed by the syphilis spirilla which is poisoned by it, whilst it has a negligible effect on the body of the diseased person. This drug is known as salvarsan, or 606, and has revolutionized the treatment of syphilis. We can confidently expect an extension of the method to the treatment of other diseases.

The poisonous nature of arsenic compounds, together with their very common occurrence, have combined to make arsenical poisoning of sufficient frequency. It is interesting to note that although the lethal dose is small, 2 grains of white arsenic being fatal, yet by prolonged usage much larger quantities can be taken without inconvenient results.

**COBALT.**—Cobalt or kobald was originally an evil spirit, and at a later date an evil spirit which haunted a copper or other mine, and prevented certain ores, cobalt ores, from giving metals when treated in the usual manner. These ores were used to colour glass blue.

**Occurrence.**—Cobalt is usually found in association with bismuth and nickel. Its chief ore is tin-white cobalt (smaltite), a cobalt nickel iron arsenide. Sulphide ores are also used. The chief supplies of cobalt ores come from the Sudbury (Ontario) district and from New Caledonia.

**Extraction.**—The Sudbury ores are first heated with a flux. Many of the impurities, including some of the iron, are converted into molten silicates which can be poured off. The impure cobalt arsenide which results is then heated in air, when the remaining iron is converted into ferric oxide ( $\text{Fe}_2\text{O}_3$ ). The resultant product is dissolved in hydrochloric acid and slaked lime added. This precipitates, amongst other things, ferric hydroxide and ferric arsenate, from which the liquid is removed and sulphuretted hydrogen ( $\text{H}_2\text{S}$ ) passed through. Bismuth, copper, etc., are precipitated as sulphides. The solution, after boiling, consists only of cobalt and nickel and on the addition of bleaching powder all the cobalt is precipitated as cobalt oxide. The nickel is then thrown down with lime.

As a rule the cobalt oxide is not further treated, since it is this substance and not the metal which is the basis of the commercial cobalt products. The metal can be prepared, however, by heating the oxide with charcoal.

**Properties.**—Cobalt is a silvery-white metal and is, after iron, which it resembles, the most magnetic of the metals, but it is very much less magnetic than iron. It has a hardness of 5.5 and a specific gravity of 8.8. It has a very high tenacity (about 27 tons per square inch). It melts at  $1,530^\circ\text{C}$ . It does not rust and is only oxidized slightly on heating. Cobalt dissolves with difficulty in acids.

**Uses.**—Cobalt metal is as yet scarcely used in commerce although it probably will be in the future. The most frequent use of cobalt compounds is as pigments, especially for glass and earthenware and in glazes. Sometimes the oxide is used for these last purposes,

but the best of them is smalt (Saxony blue) or cobalt potassium silicate. It is prepared by fusing purified cobalt ores with potassium carbonate and quartz. Another cobalt colour is cobalt blue or Thénard's blue, which is made by fusing cobalt oxide with alumina.

**MAGNESIUM.**—Magnesium was first isolated by Davy in 1808.

**Occurrence.**—Magnesium never occurs native in Nature. Its chief natural compounds are magnesite ( $\text{MgCO}_3$ ), and dolomite, a double carbonate of magnesium and calcium. This name is derived from the range of Alpine mountains, of which this mineral forms the chief constituent. Epsom salts ( $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ), kieserite ( $\text{MgSO}_4 \cdot \text{H}_2\text{O}$ ), carnallite ( $\text{KCl} \cdot 2\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ ), and kainite ( $\text{KCl} \cdot \text{MgSO}_4 \cdot 3\text{H}_2\text{O}$ ). These two latter substances are obtained on a large scale from Stassfurt. Many other substances such as olivine, mica, etc., contain magnesium.

**Preparation.**—Carnallite is now almost exclusively used. It is made anhydrous and a certain quantity of salt added. The mixture is fused in an iron pot and an electric current passed through. When cool the magnesium can be taken from the top of the mixture. It is then remelted and cast into ingots.

**Properties.**—Magnesium is a bright silvery metal which tarnishes slightly in air. It is fairly tenacious and can be worked when just below a red heat in many different ways. It can be made into wire when hot, and this wire is compressed into ribbon, in which form magnesium is usually marketed. It is also sold as a powder. Magnesium is frequently alloyed with aluminium, about 2 per cent of magnesium being the usual quantity present.

Magnesium burns in air with an extremely bright light and is therefore used in flares, etc., and as, moreover, this flame contains a large proportion of those violet and ultra-violet rays which chiefly affect the photographic plate, magnesium is often used as an illuminant when there is not otherwise sufficient light for photography. Magnesium powder, when heated with compounds of other elements, readily reduces them, *e.g.* boron and silicon can be obtained from their respective oxides.

Magnesium is not much affected by water in the cold but hot magnesium readily decomposes steam with evolution of hydrogen.

**Compounds.**—Magnesium oxide, or calcined magnesium, results from heating magnesium and certain of its compounds. It is used

medicinally. It is incandescent at high temperatures and is sometimes used instead of lime for "lime-light." It is not decomposed even when heated very strongly, and is employed as a lining for furnaces and in firebricks.

*Magnesium hydroxide* forms a crystalline compound with sugar and is used to obtain pure sugar from treacle.

*Magnesium chloride*, present in carnallite and impure common salt, is very hygroscopic, *i.e.* it takes water from the air and in so doing becomes sticky and moist. This is a disadvantage in table salt, but cotton, on treatment with magnesium chloride, becomes moist and easily spun and it is used by the cotton-spinner for this purpose.

*Magnesium carbonate* (*magnesia alba*) is much used medicinally as a remedy for indigestion, and it is also present in many tooth powders. The commercial article is always a basic magnesium carbonate, and when prepared in the cold is called "light magnesium carbonate," whilst if boiling magnesium sulphate solution be employed in its preparation "heavy magnesium carbonate" results.

*Magnesium sulphate* or *Epsom salts* was first described in 1695 as being present in certain springs at Epsom. It is now obtained from the kieserite or mono hydric magnesium sulphate of Stassfurt. In addition to its well known use as a purgative it is also used in cotton manufacture.

The so-called *citrate of magnesia* consists of bicarbonate of soda, sugar, and magnesium tartrate as well as magnesium citrate.

**TUNGSTEN.**—There are certain metals, such as tungsten, chromium, manganese, and molybdenum, which are acquiring an increasing importance, and these four will be briefly considered. Tungsten or wolfram is important in certain essential ways, *e.g.* one of its salts, sodium tungstate is used for fireproofing wood, whilst insoluble tungstates are used for making flannelette non-inflammable. The metal itself is used as a filament in Osram, etc., lamps. If it be pressed into wire 1.5 watts are used for every candle power of light produced. When "drawn" into wire ("drawn wire lamps") only 1.25 watts of current are used per candle power. Both the foregoing are the current consumptions if the lamp-bulb be evacuated. Quite recently, however, the bulbs have been filled with Nitrogen or Argon, and such lamps use

only  $\frac{1}{2}$  watt per candle power, *i.e.*  $\frac{1}{2}$  watt lamps. The old carbon filament lamps used 3.5 watts per candle power.

Tungsten, when added to steel, produces an alloy which remains hard at a bright red heat, and is thus an essential constituent of high speed steels, although vanadium is even better for this purpose than is tungsten.

The chief supplies of tungsten are derived from Burma, Portugal, New South Wales, and some from Cornwall and Colorado.

The chief commercial ore of tungsten is wolframite, *i.e.* iron manganese tungstate. Ferberite, *i.e.* iron tungstate, and hubnerite, manganese tungsten, since they contain practically the same percentages of tungsten as wolframite, are usually marketed as "wolfram" also. Scheelite or calcium tungstate is also used.

Briefly, the ores are converted into sodium tungstate by fusion with sodium carbonate and nitrate. Hydrochloric acid is then added to a boiling solution of sodium tungstate and tungstic acid ( $H_2WO_4$ ) is precipitated. The tungstic acid is then reduced with carbon or producer gas to metallic tungsten.

**CHROMIUM.**—Chromium was so called from the fact that its first known compound "crocoisite," naturally occurring lead chromate, was of a yellow colour (Greek chroma = yellow).

The metal does not occur free in Nature and the chief ore is chromite or chrome iron ore [ $Fe(CrO_2)_2$ ].

The metal is usually prepared by Goldschmidt's aluminothermic process. The chromite is first freed from iron, and then the resultant chromium oxide is powdered and mixed with aluminium powder in a crucible. This is covered with a layer of aluminium powder and sodium peroxide. This layer is very inflammable, being ignited even when brought into contact with water. In this process magnesium ribbon, however, is used as the fuse. The enormous heat evolved causes the reduction of the chromium oxide by the aluminium with which it is mixed. After the action metallic chromium is found at the bottom of the crucible.

Chromium is a very hard metal and is chiefly used for hardening steel for special purposes, *e.g.* piercing projectile heads and stainless cutlery. Such chrome iron can be made direct by smelting chrome iron ore in the electric furnace, and it may be noted that although electricity, even with available water power, is expensive for

general iron ore smelting, yet its cleanliness in use, and the fact that it does not introduce by-products, make it very suitable for the preparation of special steels such as tool steel and ferro chrome. The ferro chrome thus prepared can then be mixed with ordinary steel to give the required percentage of chromium. Such steel cannot be drilled and is used for burglar-proof safes.

Chrome steels containing nickel do not shatter and are used for armour plating.

It is of interest to record that the celebrated Damascus steel contained both chromium and tungsten which seem to have been present in the ore used.

Chromium compounds are nearly all coloured, and some of them are used as colours, *e.g.* lead chromate is chrome yellow. Sodium dichromate is largely used in industry, *e.g.* photography and dyeing, whilst certain salts containing chromium are used in the tanning of leather. Chromite is so resistant to heat that it is used for the hearths and linings of steel furnaces.

**MOLYBDENUM.**—The chief ore of molybdenum is the sulphide or molybdenum glance ( $\text{MoS}_2$ ). This gives the oxide ( $\text{MoO}_3$ ) on roasting and from the oxide metallic molybdenum can be prepared by heating with aluminium according to the Goldschmidt process.

The chief use of metallic molybdenum is for alloying with steel, which it makes very hard whilst not so brittle as does tungsten. Molybdenum steels also, like tungsten steels, retain their hardness at high temperatures and are therefore used for lathe tools, etc.

Sodium molybdate is used in pottery for producing blues in china, whilst ammonium molybdate has a great use in testing for phosphorus, especially in iron and steel analyses.

**MANGANESE.**—Manganese does not occur in the metallic state in Nature. Its chief ores are pyrolusite (manganese dioxide,  $\text{MnO}_2$ ), braunite ( $\text{Mn}_2\text{O}_3$ ), hausmannite ( $\text{Mn}_3\text{O}_4$ ), and manganite ( $\text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$ ). The metal is chiefly prepared from the dioxide by Goldschmidt's process (*q.v.*).

Manganese is an iron-grey metal with a pink-red sheen. It is very hard but rather brittle.

The metal is chiefly used to harden and toughen steel, particularly for crushing machinery, etc., although chromium is said to be better for this purpose. Manganese in the form of ferro manganese



and spiegeleisen (which can be formed direct from the ore) is used to remove sulphur and phosphorus in the manufacture of mild steel.

Pyrolusite is used for filtering water and for making glass quite colourless. It seems certain that the ancient Romans knew of this property of pyrolusite. It is also one of the ingredients in the manufacture of chlorine and bromine.

Potassium permanganate is well known as a disinfectant. A somewhat crude substitute for this substance made by fusing pyrolusite with caustic soda is put on the market as a proprietary disinfectant.

## CHAPTER VII

### NICKEL AND IRON

**NICKEL.**—Nickel seems to have been known to the Chinese almost throughout their history, but was not recognized in Europe until modern times. A nickel ore was known but was supposed to be an ore of copper, and since it did not give copper on the usual treatment was called false-copper (kupfer-nickel).

**Occurrence.**—Nickel is usually a constituent of meteorites, and since the density of the earth agrees with that of the nickel iron-alloy of which meteorites are composed, it is supposed that the mass of the earth consists chiefly of nickel-iron.

In practice nickel is always found associated with cobalt and frequently with bismuth.

The chief nickel ores are its arsenide, NiAs (kupfernickel); its sulphide, NiS (nickel blende); a sulph-arsenide, NiAsS (nickel glance), and magnesium nickel silicate ( $\text{MgNi} \cdot \text{H}_2\text{SiO}_4$ ) (garnierite).

Nickel ores come chiefly from Sudbury (Ontario) and also from New Caledonia.

**Extraction.**—Ores containing some nickel sulphide and a large quantity of iron sulphide, with usually some copper, *i.e.* the Sudbury ores, are first roasted in the air for many weeks to get rid of some of the sulphur. The roasted mass is then heated in a blast furnace with a flux. The heating and flux are so arranged that most of the iron forms a fusible slag and a matte of nickel, 20 per cent iron and copper sulphides remains.

The matte is either Bessemerized or heated in a reverberatory furnace with sand to form iron silicate (slag). The Bessemer converters, except for being small, are practically the same as those employed for iron. A purer matte, almost iron-free, results from this treatment, and is in a condition to produce metallic nickel. The matte usually contains copper and this must be separated. There are two processes in common use; either the matte is heated with coal and sodium sulphate, whereby two layers are formed, the bottom one, consisting of nickel sulphide, being roasted to form nickel oxide and then reduced by heating with sugar or flour to the

metal, or else the Mond process is adopted. In this case the matte is roasted until it consists of copper and nickel oxides. Much of the copper is then dissolved out as sulphate by sulphuric acid, and the remainder reduced at a low temperature with Mond gas (water gas—hydrogen and carbon monoxide). Crude metallic nickel results and this is then heated with carbon monoxide at from

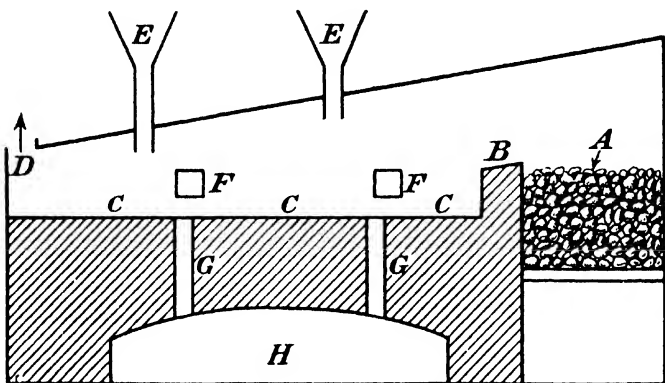


DIAGRAM OF REVERBERATORY FURNACE

*A* the fire, the fumes and heat from which pass over the wall *B* and over the material to be roasted which is on the hearth *C*. They leave the furnace by the flue *D*. The ore, etc., is introduced through the hoppers *E* and raked into position through the doors *F*. When finished the resultant substance is raked to the holes *G* down which it falls into the chamber *H*.

50°–80°. Nickel carbonyl  $[\text{Ni}(\text{CO})_4]$  is formed and is free from any impurity. When the temperature of the nickel carbonyl is raised to 200° C. it is decomposed into carbon monoxide, which can be used again, and commercially pure nickel.

Nickel can also be prepared by dissolving the roasted ore in hydrochloric acid and then precipitating first the impurities and then nickel oxide, which is reduced to nickel.

**Properties.**—Nickel is a silver-white metal, hard, tenacious, malleable, and ductile. Its specific gravity is 8.8. It melts at 1,480° C., and conducts heat and electricity fairly well. It does not oxidize in the air nor blacken, as does silver, by the action of sulphur compounds contained in the air. Alkalies, even when molten, have no action upon it. It is somewhat magnetic.

**Uses.**—Nickel is mainly used in alloys, but the metal itself is used for crucibles which have to contain alkali, for knife handles, spoons,

etc., also as a base for teapots, etc., upon which silver is deposited electrolytically. Nickel itself is electroplated on to brass and iron to prevent tarnishing.

**IRON.**—Iron has been in use from very early times. It is, however, difficult to fix any definite time as, owing to the ease with which it oxidizes, articles of iron, unless carefully preserved, completely rot away in a comparatively short time. An iron implement has been found embedded in the Great Pyramid, and iron was used (*e.g.* for chariots) in the period recorded in the Old Testament. The Romans worked iron on a fairly large scale, *e.g.* in the Forest of Dean. Their method of extraction was, however, very wasteful and expensive, and if adopted at the present day would result in iron that would have to be sold at about £400 a ton.

**Occurrence.**—Iron is sometimes, though very rarely, found naturally in the metallic state. In such cases it is probably of meteoric origin and is usually alloyed with a small quantity of nickel. Commercially, iron is always obtained from compounds which contain varying quantities of iron. The value of an iron ore depends partly upon the percentage of iron which it contains, partly upon the presence of such noxious impurities as sulphur, phosphorus, etc., small quantities of which, in the finished product, would be disastrous, and partly on the distance from coal and the difficulty of reaching a market.

The iron ore with the highest percentage of iron is magnetite ( $\text{Fe}_3\text{O}_4$ ). This occurs unusually pure and may contain 72 per cent of iron. The chief supplies are obtained from Gellevara in Sweden, and the Mesibe Hill district of Lake Superior and Madras. In Sweden and U.S.A. it can be quarried, and in the American case this is done by steam navvies working on rails at a very cheap rate. The Swedish ore is so pure that despite its long journey to Narvik, and thence to the Clyde, it is often used there in preference to local ores.

Ores containing  $\text{Fe}_2\text{O}_3$  are also of great importance and have an enormously wide application. This body may either be without water, when it is called red haematite, or hydrated, when it is called brown haematite. Red haematite occurs at the Canadian side of Lake Superior; in the U.S.A., all the way from New York State (Clinton) to Birmingham in Alabama, and in Cumberland. Brown

haematite (which may be red in colour, when it is called rubio ore) is obtained very pure from the north of Spain (Bilbao, San'tander). Enormous quantities of this ore are used in South Wales. Brown haematite is also obtained from Northamptonshire, the Forest of Dean, Ireland (bog iron ore), France, Germany, Canada and Sweden.

The Lorraine deposits of iron ore consist of impure phosphoric brown haematite. Iron carbonate (spathic iron ore) is worked in large quantity in Styria.

When ferrous carbonate contains clay (clay ironstone) or coal (blackband) it can be worked cheaply (Cleveland, York, and Staffordshire).

The most commonly occurring iron compound is iron pyrites ( $\text{FeS}$ ), but it is as yet too expensive to work for iron. It is, however, employed in the preparation of sulphuric acid and for the copper that it sometimes contains.

**Extraction.**—Many different methods exist for extracting iron from its ores. The one adopted in any particular locality depends on the ore employed, on the available fuel, and on the use to which the iron will be put.

Primitively, iron is always extracted by reducing the ore with wood charcoal fires. The trees of the old Wealden Forest were cut down to provide timber for this purpose in the days when the Three Bridges district of Sussex was the chief iron district in England. Iron is still manufactured in this way in India. Wherever produced the iron is usually of very high quality.

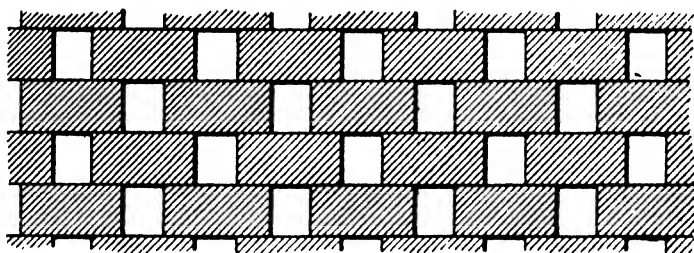
The most used method at the present day is that of the blast furnace. This is an iron-cased brick building about 60–90 ft. high with a varying-sized circular section.

There is a hopper closed by cup and cone valve at the top to admit the fuel, ore and flux charges, and exit pipes at two levels at the bottom to allow the heavier iron and the lighter slag to be drawn off. Above these pipes are other pipes (*tuyères*) by which the blast is admitted. The blast consists of the furnace gases, which are unable to escape into the air because of the cup and cone valve. They are drawn off near the top, where the furnace is coolest, and led through pipes into a chamber where the dust, etc., is deposited. This dust contains potash salts and is used as manure. The gases then pass into a stove packed with bricks

as shown below, and there burnt with air drawn in from outside. The temperature of this stove is carefully regulated by the amount of furnace gases burnt and the amount of cold air admitted. The products, carbon dioxide, water, oxygen and nitrogen are then blown into the furnace.

The changes which take place in the furnace are roughly as follows—

The blast, by the time it reaches the top of the furnace, has



BRICK TIERS INSIDE STOVE

become reduced by the coke to carbon monoxide and some hydrogen, + of course unchanged nitrogen. The carbon monoxide reacts with the iron oxide which is near the top of the furnace, forming iron and carbon dioxide ( $\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow \text{Fe} + \text{CO}_2$ ). The further down into the furnace any unchanged ore reaches, *i.e.* the hotter it gets, the more quickly does this reaction proceed. Any residue of ore is reduced by the coke ( $\text{C} + \text{Fe}_2\text{O}_3 \rightarrow \text{CO} + \text{Fe}$ ). These reactions take place below the melting point of iron and the metal assumes a spongy form and reduces some carbon monoxide to carbon, with which it eventually combines. As is usual in solutions, the melting point of a solution of carbon in iron is lower than that of the pure metal and soon the iron-carbon compound melts and flows to the bottom of the furnace. This is periodically drawn off into sand moulds, and the rough castings are called pigs and the crude cast iron is known as pig iron.

A good blast furnace can produce as much as 5,000 tons of pig iron per week, involving the use of 5,000 tons of foundry coke and as much as 25,000 tons of gases for the blast. The flux used is

nearly always limestone, and about 3,000 tons would be required to produce the above 5,000 tons of pig iron.

When one considers that as much coke is required as pig iron produced one can appreciate the importance of cheap fuel to the iron industry.

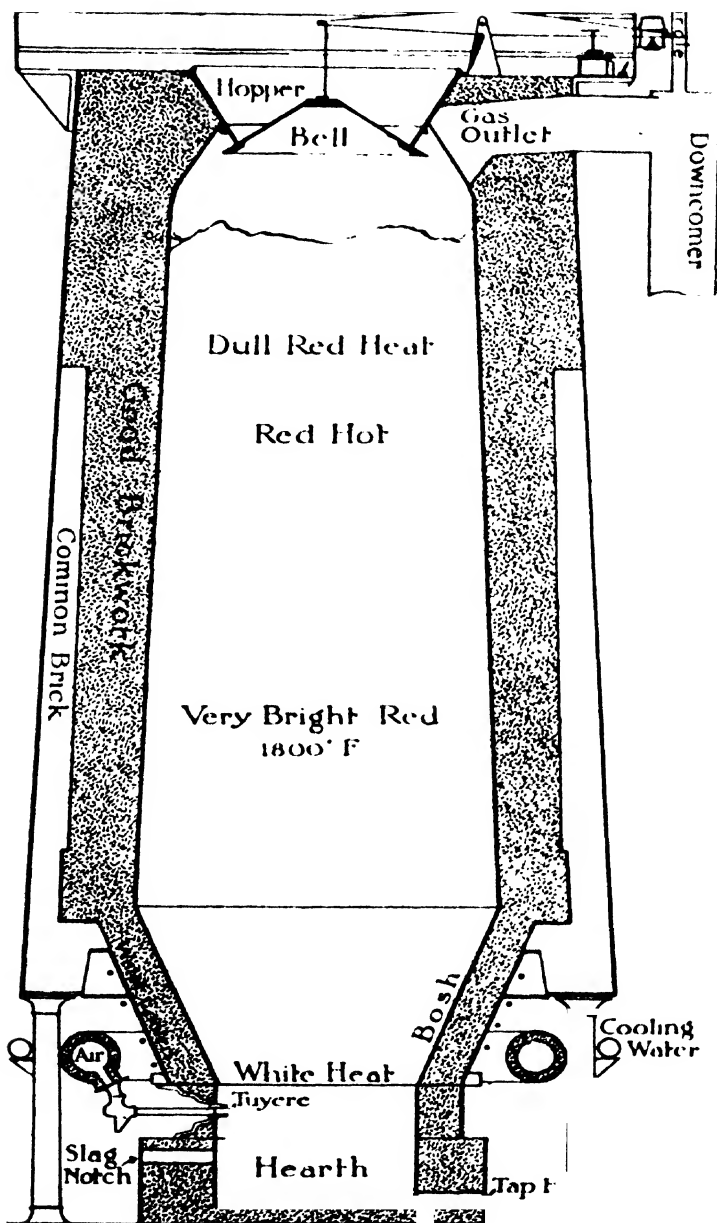
The cast iron contains about 5 per cent of impurity, chiefly carbon, phosphorus, sulphur, silicon and manganese, and of these phosphorus and sulphur when present in any quantity are highly injurious both to the cast iron itself and to any product, *e.g.* wrought iron, which may be made from it. They both cause brittleness, sulphur to the hot metal (red short) and phosphorus to the cold cast iron (cold short). Manganese helps to remove sulphur as manganese sulphide, which passes into the slag.

A cast iron containing from 5 per cent of manganese is called spiegeleisen, whilst when the percentage of manganese is high, 20-80 per cent and even more, the product is known as ferro-manganese.

Cast iron is purified by remelting in a cupola-furnace—an iron and fire-brick blast furnace of small size—with a little coke and a small quantity of flux. The molten iron descends to the bottom and is drawn off direct into the moulds which, for small objects, are usually made of green sand.

Wrought iron is usually made from cast iron by removing the carbon and other impurities. This is done in a puddling furnace, which consists essentially of a mild-steel water-cooled hearth covered with a thick layer of ferric oxide, which last substance is intended to convert impurities into volatile oxides. The pigs when put into this furnace soon melt, and as the impurities burn off the iron becomes more and more pasty. The plastic mass is puddled, *i.e.* stirred, with long iron bars introduced, by men, through holes in the side of the furnace, and when sufficiently pure the product is withdrawn and rolled. The rolled bars are then reheated and the product is wrought iron, *i.e.* practically pure iron containing less than .5 per cent of total impurity and less than .1 per cent of carbon. Wrought iron is soft and tenacious. When red hot it can easily be worked and welded, and is therefore greatly used in "smithing" work.

Mild steel is really a rather impure form of wrought iron and has



**BLAST FURNACE**



to a great extent replaced wrought iron in use. It can be made direct from a pure iron ore, *e.g.* magnetite, and this is done on a large scale in small furnaces in America and at Motherwell. A sufficiency of manganese is added during manufacture to remove sulphur, etc.

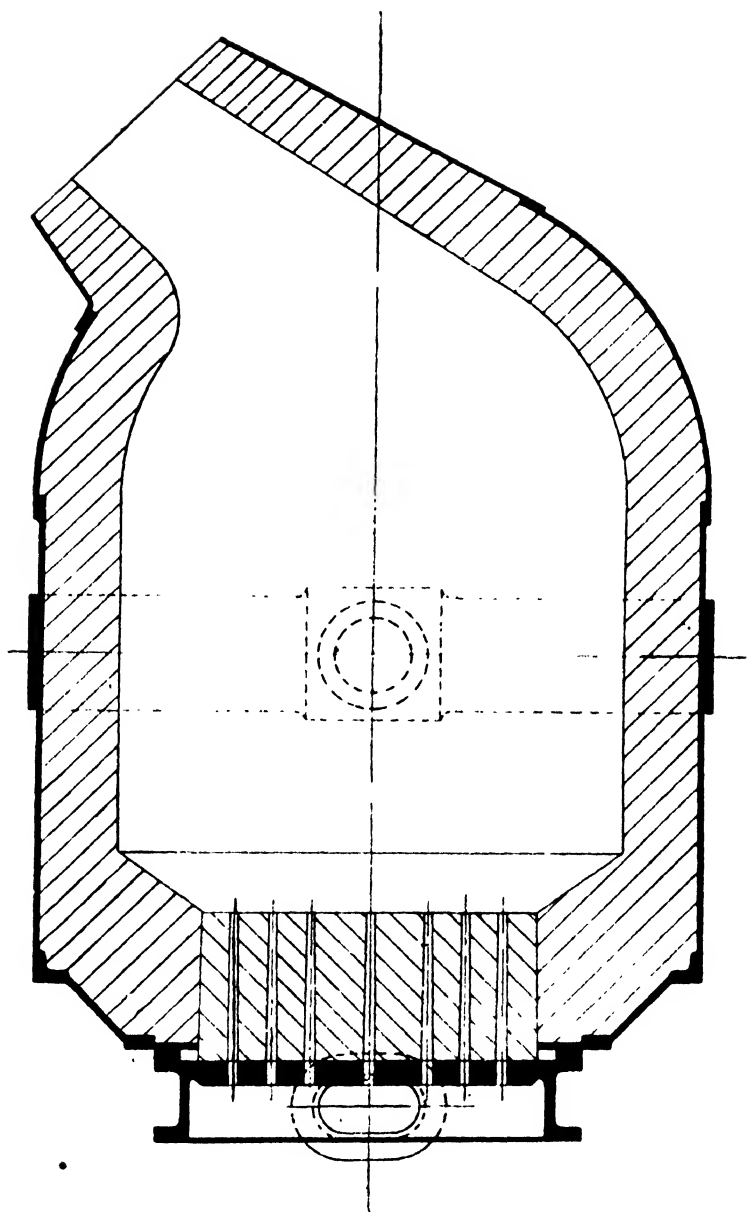
**The Bessemer Process for Manufacturing Steel.**—Bessemer, in 1856, discovered that a fair approximation to wrought iron could be produced by blowing air through molten pig iron, and the commercial application of this discovery—the Bessemer process—is responsible for most of the iron other than cast iron now in use for all but special purposes as well as in the manufacture of copper. The Bessemer converter is a pear-shaped vessel capable of taking about 10 tons of pig iron and of being rotated to any position. It is made of wrought iron and lined with a mixture of clay and sand (silica) or with gannister.

Molten pig iron is poured into the converter and air blown in at the bottom. This oxidizes the impurities and the heat of reaction is sufficient to keep the metal molten. In addition the silicon manganese, etc., combine with the converter lining to form a soluble silicate—slag—which floats on the top. The carbon is converted into carbon monoxide by the blast, and this gas burns at the mouth of the converter, together with particles of iron, etc. When this flame stops, the calculated amount of spiegeleisen is added to produce steel of the correct composition.

The first results of this process were not encouraging, but it was soon discovered that so long as phosphorus and sulphur-free pig iron was used that the product was quite good. When these elements were present, however, the product was a failure.

Thomas and Gilchrist soon showed, however, that if a basic lining, *e.g.* magnesium calcium carbonate (dolomite), replaced the acid silicious ore that phosphates, etc., were formed containing practically all the sulphur and phosphorus, and which floated on the top as slag. This slag, basic slag as it is called, is in great demand as a manure for plants.

**The Siemens Process.**—Siemens and Martin mix pig iron with scrap iron and iron oxide, and heat the mixture on an open hearth in a lined basin by means of a blast of producer gas. If the pig iron is phosphoric or contains sulphur a basis lining is used, otherwise, a silicious one.



BESSEMER CONVERTER

**Cementation Steel.**—When wrought iron is heated with charcoal for about a week it combines with some of the carbon, acquires a blistered surface, becomes much harder, and the product is known as blister steel. If the operation be now repeated shear steel, formerly in great demand for cutlery, is produced.

Blister steel is remelted in crucibles, and crucible steel or cast steel results, which is now the chief material of the cutler. Such steel is sometimes called tool steel.

Special steels are made by this process on the introduction of calculated quantities of other metals to make alloys.

Thus, chromium steel is very hard and is used for armour-piercing projectile heads and also, since when it contains some silicon it is chemically inert, it is used for “rustless,” or stainless, cutlery.

Nickel steel and vanadium steel are very elastic and tenacious. Nickel steel is used for protective armour, since it does not crack easily, and vanadium steel is largely employed in motor car work.

Manganese steel is used in crushing machinery because of its toughness, whilst tungsten confers upon steel the property of remaining hard, even while red hot.

Tungsten steel (high speed steel) is thus essential where rapid revolution of a cutting edge or other continuous cutting is required, *e.g.* in lathe tools.

It has been shown that wrought iron is nearly pure iron, and that mild steel contains only a slightly greater amount of carbon,  $\cdot 1$ – $\cdot 25$  per cent. Medium and hard steels can contain up to  $1\cdot 5$  per cent of carbon, usually  $\cdot 4$ – $1\cdot 0$  per cent, whilst cast iron will contain about  $3\cdot 0$  per cent.

In cast iron some of the carbon is combined with the iron as carbides of iron, whilst some is present as carbon. When most of the carbon is present in the elemental state the pig iron is grey, when most of the carbon is combined the pig iron is white on fracture, whilst approximately equal quantities of free and combined carbon give “mottled” pig iron. Cast iron has a pronouncedly crystalline fracture and is very brittle. It is not at all tenacious but will stand an enormous compressional force.

Steels other than mild steel are almost certainly solid solutions of iron carbide in iron. The melting point of steel varies with the amount of carbon it contains.

The condition of these solid solutions, and consequently the properties of steel, is affected by heat and cold, and this property is made use of in hardening and tempering steel. Thus the sudden cooling of steel which has been strongly heated results in a very hard, brittle substance, whilst slow cooling will result in a substance from which wire can be drawn. Many different properties can be conferred on steel by heating, reheating, cooling slowly, quenching, rolling hot, etc., and by combinations of these operations.

The most important deleterious property of iron is that it is acted upon by the atmosphere. The exact mechanism of the action is unknown, but it is certain that dry iron is very little acted upon by dry air, and that action is most rapid when the air is moist and contains carbon dioxide. The product of decomposition is always acid and consists principally of ferric and ferrous oxides. Combination is greatly accelerated by the presence of acid-forming substances, *e.g.* sulphur, and great trouble has been incurred by using coke breeze containing sulphur in ferro-concrete buildings. There are various methods in use for preventing the rusting of iron. The most common is, of course, painting with ordinary paint. One of the most efficacious is painting with Portland cement, and this is of great use in steel buildings.

Iron is the most strongly magnetic substance known and is exclusively used for all work involving electro-magnetics, *i.e.* dynamos, electric motors, etc.

## CHAPTER VIII

### NON-METALLIC ELEMENTS OF COMMERCIAL IMPORTANCE

**HYDROGEN.**—Hydrogen is a gas which, although emitted to a small extent by some volcanoes, is never found in our atmosphere. This is probably because the average velocity of the hydrogen molecule is so great that the fastest moving molecules travel at a rate greater than the attraction of the earth and so they pass off into space.

**Preparation.**—Many metals, *e.g.* iron, zinc, sodium, calcium, magnesium, break up water (sometimes hot and in some cases cold) with the liberation of hydrogen ; and since scrap iron is very cheap one commercial method of preparing hydrogen is by passing steam over hot scrap iron. When an electric current is passed through water (slightly acidulated) hydrogen is set free at the cathode. Since the acid is practically unaffected this is a cheap way of preparing hydrogen when electricity is cheap, as it is in the neighbourhood of abundant water power.

**Properties.**—Hydrogen is an extremely light, colourless, insoluble gas. It is so light that air is heavier with regard to it than is mercury with reference to water. It is extremely inflammable, and a mixture of hydrogen and air is explosive. When burned it produces water, hence its name, which means "water producer."

It is used as a means of producing great heat in the oxy-hydrogen blowpipe, although in this case it is now being rapidly superseded by acetylene. Hydrogen is usually used for filling the gas containers of airships, *e.g.* Zeppelins. A great objection to its employment is the risk of fire, and it is proposed now to use instead another gas, helium, which, although twice as heavy as hydrogen, is nevertheless non-inflammable. Helium is contained in small quantity in natural gas in many parts of the world, *e.g.* France, Canada, and U.S.A., and the natural gas of Bow Island, Alberta, which is conveyed by a 160 mile pipe line to Calgary, contains about 33 per cent of helium or about  $10\frac{1}{2}$  million cubic feet a year. Professor Mc.Clennan has actually obtained 800 cubic feet in

three days, and estimates that it will be possible to extract all the helium at a cost of  $2\frac{1}{2}$ d. per cubic foot.

Hydrogen is an important constituent of coal gas.

**OXYGEN.**—Oxygen, which was first discovered independently by Priestly and Scheele in 1772–4, is now a fairly important commercial substance. It is a constituent of air, water, and almost all rocks, plants, and animals.

**Preparation.**—Nowadays the liquid air preparation of oxygen has eclipsed all other large-scale methods. In this process air is forced down a long tube at about 200 atmospheres pressure. It is then allowed, suddenly, to expand and the air is thereby cooled. The cooled air returns by a tube which surrounds the inlet tube, and consequently cools the incoming compressed air. This in its turn is expanded, cools, and passes out, cooling further air as it does so. Eventually the air liquefies. This liquid air consists chiefly of a mixture of  $\frac{1}{5}$  nitrogen and  $\frac{4}{5}$  oxygen. Now liquid nitrogen boils at a lower temperature than does liquid oxygen, and therefore if the pressure be reduced somewhat the nitrogen boils off first leaving behind practically pure liquid oxygen. A further reduction of pressure causes the liquid oxygen to boil in its turn and the gas is collected in iron cylinders at a pressure of about 120 atmospheres. By this method nitrogen and argon are also obtained and used for filling electric bulbs (gas filled lamps). The best mixture appears to be 85 per cent argon and 15 per cent nitrogen. Such half-watt lamps burn only  $\frac{2}{3}$  of the current that vacuum lamps will do.

**Properties.**—Oxygen is a colourless gas, nearly but not quite insoluble in water, and allows substances to burn in it much more vigorously than in air.

All animals and fishes must have oxygen to breathe in order that their blood may be purified, whilst plants also breathe in oxygen in the dark. In the light, however, plants exhale oxygen.

**Uses.**—Oxygen is used for producing high temperatures, either with hydrogen in the oxy-hydrogen blowpipe, or with acetylene in the oxy-acetylene flame. Oxygen is used as a bleach, in which case bodies which easily produce it, *e.g.* per-borates and per-carbonates, are used. Oxygen is also used medicinally in cases of difficult breathing, *e.g.* in the treatment of pneumonia and asthma.

**CHLORINE, BROMINE AND IODINE.**—These three nearly related elements have very similar properties, but since there are much greater supplies of chlorine available than of the others, chlorine is much more frequently used.

**Preparation of Chlorine.**—Chlorine is obtained as a by-product in the preparation of metals and hydroxides by the electrolysis of their chlorides, especially in the Castner process for producing caustic soda from salt (*q.v.*).

Chlorine is also produced by the action of hydrochloric acid on manganese dioxide (pyrolusite). Manganese dichloride is formed in solution. The liquid is treated with milk of lime (a paste of slaked lime and water), and then has air blown through it. Calcium manganite, which can be regarded as a compound of lime and manganese dioxide ( $\text{CaO MnO}_2$ ) is thereby produced and forms a sludge (Weldon mud) at the bottom of the tank. This mud can be fed straight into the apparatus again where, on the addition of hydrochloric acid, it behaves similarly to manganese dioxide and produces more chlorine. Thus there is no need to recharge with fresh manganese dioxide.

Another method of preparing chlorine is by the Deacon process. In this case hydrogen chloride and air are passed over pumice, soaked in cuprous chloride and kept at high temperature. As a result chlorine is produced and the cuprous chloride, after change, is re-formed. Chlorine produced by this process contains impurities, but these do not adversely affect the conversion of the chlorine into bleaching powder.

**Properties of Chlorine.**—Chlorine is a greenish-yellow gas with a pungent, unpleasant smell. It is somewhat soluble in water and very poisonous (hence its use as a poison gas in the war). It is also a germ poison. It is quite easily liquefied. It has a pronounced bleaching action.

**Uses of Chlorine.**—Chlorine is used as a bleach, especially in the paper industry and in preparing certain important compounds, including bleaching powder, or chloride of lime. Slaked lime is spread on shelves in a room and chlorine passed in. As a result of this action bleaching powder ( $\text{Ca OCl}_2$ ) is produced. Bleaching powder always smells of chlorine and readily gives that gas when treated with acid.

Fabric to be bleached with bleaching powder is treated with water and that substance and then with very dilute acid.

Bleaching powder is used as a deodorant and disinfectant.

Chlorine itself is used in the extraction of gold from its crushed ores (*q.v.*).

**BROMINE.**—Bromine was first prepared in 1826. Its compounds are present to a small extent in sea water, but its chief available source at the present time is from the residues (mother liquors) in the Stassfurt potash preparation. The bromine is there present as magnesium bromide. The liquor, which contains only a small proportion ( $\frac{1}{4}$  per cent) of magnesium bromide, is mixed with steam and chlorine by trickling over earthenware balls up which the steam and chlorine pass. The chlorine replaces the bromine ( $\text{MgBr}_2 + \text{Cl}_2 = \text{MgCl}_2 + \text{Br}_2$ ), which passes on and is condensed to a dark red liquid in a worm condenser. It is purified by distillation.

Bromine can also be obtained by electrolysis of the mother liquors by a current of appropriate density.

**Properties.**—Bromine is a dark red volatile liquid with a highly objectionable smell (bromos = stench). It boils at  $59^\circ \text{C}$ . It is poisonous both on inhalation and also to the skin, which it badly blisters. It is not so chemically active as chlorine, which element, however, it greatly resembles. It possesses some bleaching properties.

**Uses.**—Bromine itself is used in metallurgy, as a solvent. It is used in the organic chemical industries, especially the dye-making industry. For instance, it is a constituent of eosin, the colouring matter of ordinary red ink. A mixture of bromine and kieselguhr is sold under the name of "solidified bromine" (bromine solidificatum) as a disinfectant.

Potassium bromide (KBr) is used on a comparatively large scale in photography as a restrainer, etc., and in medicine as a sedative and hypnotic.

Silver bromide is used in photographic plates and papers.

**IODINE.**—Iodine was first obtained from the ash of seaweed (kelp) in 1812.

**Occurrence.**—Although iodine is present in kelp (about .2 per cent) and to a slight extent in sea-water, yet it is now obtained



almost exclusively as a by-product from the sodium nitrate beds of Chile. After the nitrate is crystallized out the mother liquor is concentrated until it contains up to 20 per cent of sodium iodate. This is then allowed to crystallize out. The iodate can be purified by recrystallization. If iodine be required a solution of the iodate is heated with sodium bisulphite solution and the iodate is reduced to iodine, which settles at the bottom and is pressed dry into blocks. The iodine so obtained is then purified by sublimation. If the iodine be required chemically pure it must be dissolved in potassium iodide solution and precipitated from it.

**Properties.**—Iodine is a violet crystalline solid which sublimes without melting (unless under pressure). The word *iodine* means violet. It is barely soluble in water, fairly easily soluble in alcohol, and easily soluble in potassium iodide solution and chloroform. It is irritant but antiseptic. It colours the skin yellow and reacts at once with many metals. It gives a characteristic colour with starch.

**Uses.**—Iodine is used medicinally either by itself or in solution, as a powerful antiseptic, in particular as a preventive against tetanus.

Many organic compounds of iodine are also antiseptic, *e.g.* the well-known iodoform. Potassium iodide is used in cases of anaemia. Many dyes contain iodine.

Potassium and silver iodides are both used in photography, silver iodide being an important constituent of "plates."

**CARBON.**—Carbon forms the chief part of the residue on the distillation of all organic substances. Coke and wood charcoal will be dealt with under FUEL, and diamond, a crystalline form of carbon, under PRECIOUS STONES. In addition to the cases cited there are, however, other forms of carbon, *e.g.* graphite, bone charcoal, etc.

Bone charcoal is made by distilling bones ; it contains, however, only a small proportion of carbon, the bulk of it being phosphates. The phosphates can be removed by hydrochloric acid when "ivory black," the art colour, is obtained. When blood (slaughter-house refuse in Germany) is distilled blood charcoal results. Both bone and blood charcoal are wonderful filtering agents. Thus brown sugar solution is boiled with one or other of these varieties of

charcoal and the solution is decolorized, furnishing white sugar, and many other organic substances can be similarly purified, whilst bacteria can be removed from drinking water by filtering through animal charcoal.

Very good carbon is obtained by heating nut shells, *e.g.* coconut shell.

**GRAPHITE.**—Graphite (plumbago or blacklead) is found naturally associated with micascist, granite, etc., in beds and sheets, in Ceylon, Siberia, Canada, Germany, and in small quantity at Barrowdale (Cumberland). It is crystalline and much used for "lead" pencils, electrotpe moulds, and for crucibles for use in the electric furnace. For this latter purpose it is now made artificially, especially at Kinlochleven and the Niagara Falls, by heating coke, first ground up with tar or treacle, in the electric furnace, when the coke becomes crystalline. It does not melt and is practically non-volatile even at the highest temperatures.

Incidentally, at the Niagara Falls coke is heated with sand in the electric furnace and carborundum (carbon silicide), an immensely hard substance not attacked by acid, results.

Graphite is used as a lubricant, for steam joints, etc.

**SULPHUR.**—Sulphur has been known from the very earliest times. It occurs free in Nature wherever volcanic activity is manifest, and in many other areas, in particular in Sicily, Italy, Iceland, Etrofu (Japan), Louisiana, Utah, Wyoming, etc., and New Zealand. There was some sulphur in Mexico (at the summit of Pococatapetl), and Prescott relates how the Spanish invaders, running short of gunpowder, ascended that mountain and decided by lot who should descend into the crater and get the sulphur necessary to manufacture more powder. Subsequently a mine was established in the crater at a height of 18,000 ft.

Sulphur is a constituent of many metallic ores, but is only obtained profitably from one, *e.g.* iron pyrites.

Native sulphur is either found directly at the vents of volcanoes (solfataras) or else as a degradation product of huge beds of gypsum (hydrated calcium sulphate).

Sulphur ore when mined usually contains up to 25 per cent sulphur. The excavated ore is made into huge heaps (about 2,000 tons) and fired from the top. Some of the sulphur burns

and the heat generated melts the remainder, which flows into moulds.

In America the sulphur is melted in the mine by superheated steam led in through pipes. The molten sulphur flows to a sump, whence it is pumped to the surface through pipes inside the steam pipes.

For many purposes the sulphur can be used in the crude state, but should it be required pure it is distilled from iron retorts. The first sulphur which comes over condenses to a fine powder (flowers of sulphur) but afterwards it collects in the molten condition and is cast into rolls or lumps.

**Properties.**—Sulphur is a pale yellow crystalline solid melting at  $115^{\circ}\text{C}$ . and  $120^{\circ}\text{C}$ . according to the shape of the crystals. It boils at  $445^{\circ}\text{C}$ . It is very reactive chemically, uniting at once with many metals even in the cold, *e.g.* blackening of silver. It readily burns, forming sulphur dioxide.

**Uses.**—Sulphur is used in the preparation of sulphur dioxide and sulphuric acid, in the manufacture of gunpowder, in making india-rubber from caoutchouc, in vulcanizing, and in the manufacture of matches. Sulphur is also used medicinally and as a germicide and insecticide. It is a very fair insulator.

**PHOSPHORUS.**—Phosphorus is a constituent of the human body and was first obtained by distilling a mixture of sand and urine in about 1668, and about 100 years later Scheele prepared it from bone ash. Phosphorus at one time meant any substance which glowed in the dark, and it was not until some time after the discovery of the element now known as phosphorus that the word was restricted to it.

**Occurrence.**—Phosphorus is a constituent of all protoplasm. In Canada, Spain, and S. Carolina it exists in the form of apatite  $[3\text{Ca}_3(\text{PO}_4)_2, \text{CaCl}_2]$  and fluor apatite  $[3\text{Ca}_3(\text{PO}_4)_2, \text{CaF}_2]$ . Most iron ores contain some phosphorus.

**Manufacture.**—The phosphate, either bone ash or apatite, is heated in the electric furnace with coke and sand. The phosphorus distils off and a molten slag (mainly calcium silicate) remains. This can be drawn off and more charge added without interrupting the process. This is the new and economical method. An older method first of all treats the calcium phosphate with sulphuric acid,

forming a solution of phosphoric acid and calcium sulphate. The solution of phosphoric acid is then concentrated, mixed with coke and heated in clay retorts, when phosphorus distils over.

Various methods are employed to purify the crude phosphorus. They consist essentially of oxidizing out impurities from the molten phosphorus under water.

The product of either of these processes is a soft white-yellow waxy solid melting at  $44^{\circ}\text{C}$ . It is spontaneously inflammable just above its melting point, and since it oxidizes in air under ordinary conditions with evolution of heat, the heat so produced is often sufficient to ignite the phosphorus. In other words, yellow phosphorus will catch fire if left in air and in consequence it is always kept in water.

When yellow phosphorus is heated, out of contact with air, to a temperature of  $250^{\circ}\text{C}$ . it is converted into a red solid which is also phosphorus; an allotrope, as it is called. A molecule of red phosphorus probably contains a different number of atoms from a molecule of yellow phosphorus. Red phosphorus is purified by grinding in water and then boiling in caustic soda solution. •

Red phosphorus is a red amorphous or minute crystalline solid which is not inflammable until temperatures above  $300^{\circ}\text{C}$ . are reached, and then only because some of it is reconverted into the yellow variety.

Yellow phosphorus is very poisonous and workers in it are liable to phossy-jaw, a rotting of the bones (caries), particularly of the jaw. According to the late Sir William Ramsay, however, this would not occur if the operatives washed their hands before eating. Red phosphorus is not poisonous.

**Uses.**—The chief use of phosphorus is in the manufacture of matches. A match consists essentially of a stick of wood or wax headed by a substance, or two substances, which unite with flame on friction. Generally the flame is too sudden and short to ignite wood and the wood in matches is kindled by an intermediate layer of paraffin wax.

**Manufacture of Matches.**—Either veneers of pine are cut into appropriate sprigs, or blocks of wood the length of two matches are slit into strips. In the latter case the strips are dropped on a belt with each end projecting and then the belt is coiled up. Both ends

of the splints are then dipped in molten paraffin. After drying the matches are then dipped into a paste consisting of an oxidizing agent (either potassium nitrate, potassium chlorate, or manganese dioxide) and an easily inflammable body (yellow phosphorus or red phosphorus) and glue to make the mixture stick. This paste is usually dyed.

The matches produced with the above paste would be "strike anywhere" matches, but the risk to the workers of using yellow phosphorus has led to the use of phosphorus sesqui sulphide instead of phosphorus, and also to a type of "safety match" in which the inflammable substance is not present in the match but, in the form of red phosphorus, on the side of the box.

When phosphorus sesqui sulphide ( $P_4S_3$ ) is used the matches will strike on rough surfaces not specially prepared.

Calcium phosphide is made by warming calcium and yellow phosphorus together under naphtha. This substance is spontaneously inflammable when water is added to it. It is therefore used in flares and in patent lifebelts (for night use).

When phosphorus is heated with tin, tin phosphide results, and when this substance is dissolved in molten copper the well known phosphor bronze is produced which, amongst other uses, is a splendid bearing metal. Phosphor bronze contains from 2-2.5 per cent phosphorus.

Vermin killers which destroy the flesh of the dead vermin, and so prevent unpleasant smells, contain phosphorus.

Phosphorus salts will be considered under PHOSPHORIC ACID.

## CHAPTER IX

### MINERAL ACIDS, ALKALIES, AND SALTS

**ACIDS.**—As an introduction to this chapter it will be as well to explain what are meant by the terms *acid*, *alkali* and *salt*. Originally acids were so named from the fact that most of them had a sharp sour taste, supposedly produced by the pricking of the tongue with numerous sharp tiny needles. Later, acids were all supposed to change the colour of certain vegetable dyes, *e.g.* to turn blue litmus red.

Nowadays we define an acid as a substance which gives positive hydrogen ions in solution. When members of a large class of substances dissolve, the molecules are broken up into parts called "ions," which travel about at a rapid rate in the solution. These "ions" carry electric charges—"electrons." Thus, when common salt dissolves in water, some of the salt molecules ( $\text{NaCl}$ ) break up into ions:  $\text{Na}^+$  positively charged, and  $\text{Cl}^-$  negatively charged. If an electric current be passed through such a solution the positively-charged ions, *e.g.*  $\text{Na}^+$ , will move to the negative electrode or cathode, and are then termed "cations," whilst the negatively-charged ions move to the positive electrode or anode, and are therefore called "anions." If a substance or solution give positively charged hydrogen ions,  $\text{H}^+$  then it is said to be an acid, *e.g.* hydrogen chloride, in solution, gives  $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$ , and it is therefore an acid (hydrochloric acid).

**Alkalies.**—When the ashes of sea or land plants are added to red litmus solution it at once assumes a deep blue colour. Hence alkalies (*al kali*, Arabic for "the ash") used to be defined as substances which turned red litmus blue. They are now, like the acids, defined electrochemically. All alkalies give, directly or secondarily, negative hydroxyl ( $\text{OH}^-$ ) ions on solution.

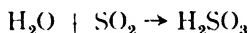
Thus caustic soda ( $\text{NaOH}$ ) becomes  $\text{Na}^+$  and  $\text{OH}^-$  on solution. Therefore caustic soda is an alkali.

**Salts.**—A salt is a substance formed by replacing the hydrogen

of an acid by a metal. Mineral acids were acids derived entirely from lifeless matter and in particular sulphuric, nitric and hydrochloric acids.

In this chapter other inorganic acids of commercial importance, *e.g.* boric and phosphoric acids, will be considered as well.

**SULPHUROUS ACID.**—When sulphur is burned in air a pungent smelling gas results called sulphur dioxide. This gas is soluble in water and the solution is an acid, sulphurous acid—



Sulphurous acid is not so important as its anhydride sulphur dioxide, and we shall consider the properties of the latter here.

**Manufacture of Sulphur Dioxide.**—Sulphur dioxide is produced in large quantity in the roasting of various sulphide ores, *e.g.* galena, etc. In the case of zinc blende, zinc sulphide, the sulphur dioxide so produced, can be easily purified, and this is one of the chief commercial sources of the gas. The gases from the furnaces are led over coke and water. The sulphur dioxide dissolves and the solution is heated by the flue gases until all the sulphur dioxide is driven off again. This is dried by sulphuric acid and compressed in a bronze pump to a pressure of not more than  $3\frac{1}{2}$  atmospheres. Under such a pressure it becomes liquid and the liquid is drawn off into “siphons” like soda-water siphons, except that the inner tube stops short just inside the bottle and above the level of the liquid. The flow is controlled by a screw and not a lever. When the bottle is upright sulphur dioxide gas is delivered, when on its side or inverted the liquid is obtained.

**Uses of Sulphur Dioxide and Sulphurous Acid.**—They are used as bleaching agents, especially for straw, wool, and silk. Sulphur dioxide and its solution are pronouncedly disinfectant and are very largely used as fumigants for rooms which have been occupied by people with infectious diseases and also for bedding, clothes, etc. These substances are also used to destroy vermin, fleas, etc.

Much sulphur dioxide and sulphurous acid are used in the preparation of sulphites (sodium sulphite, sodium bisulphite, and meta bisulphite) which are merely convenient vehicles for storing and applying sulphur dioxide for bleaching purposes.

These substances are also used in photography.

**SULPHURIC ACID, OR OIL OF VITRIOL.**—Sulphuric acid has been known at least 700 years and Basil Valentine described its preparation nearly 500 years ago. His method, by the destructive distillation of ferrous sulphate, is still a laboratory preparation at the present day. Sulphuric acid was produced on a commercial scale in 1740. At the present day sulphuric acid forms a most important article of commerce, and Great Britain alone produces over 1,100,000 tons a year, whilst the world production exceeds 4,000,000 tons per annum.

**Manufacture.**—Sulphuric acid is produced by two chief methods, the chamber process, and the contact process. Each is a means of oxidizing sulphur dioxide ( $\text{SO}_2$ ) cheaply and rapidly into sulphur trioxide ( $\text{SO}_3$ ).

**The Chamber Process.**—There is a very fine model of the plant used in the South Kensington Museum (Science). Short of a visit to a factory itself the model is well worth inspection.

In principle sulphur dioxide is oxidized by nitrogen peroxide ( $\text{N}_2\text{O}_4$ ) to sulphur trioxide. The nitrogen peroxide is ultimately reduced to nitric oxide ( $\text{NO}$ ) which gas, however, combines at once with oxygen in the air to form nitrogen peroxide again, which can be used afresh and so on.

Thus the chamber process is really a scheme for oxidizing sulphur dioxide by the oxygen of the air.

The sulphur dioxide is made by heating iron pyrites in "pyrites burners" or by burning sulphur direct.

The gas from the pyrites burners only contains about 7 per cent of sulphur dioxide. This hot gas is made to heat a mixture of sulphuric acid and sodium nitrate, thus causing nitric acid to distil off. The nitric acid is at once reduced to nitric oxide and some sulphur dioxide is oxidized to sulphur trioxide and combining with water from the nitric acid becomes sulphuric acid. (It should be remembered that the nitric acid produced here is only intended to make up for unavoidable waste of nitrogen peroxide. Theoretically it should not be necessary.)

The whole mixture now passes up into a Glovers tower, where it meets a descending stream of sulphuric acid, part of which is dilute acid freshly made, and part strong sulphuric acid which has been used to dissolve the nitrous fumes in the Gay Lussacs tower at the end



of one cycle of the operation. The Glovers tower is packed with flints and in it more of the sulphur dioxide is oxidized, whilst in addition the dilute sulphuric acid from the chambers is concentrated by the hot uprising gases.

The unoxidized sulphur dioxide and the nitrous fumes now pass successively through three leaden rooms or chambers, as they are called, each as big as a fair-sized lecture hall. Into these chambers steam, or a very fine misty spray of water, is injected and the remainder of the  $\text{SO}_2$  is now oxidized, usually in the first two chambers only. The sulphur trioxide produced at once combines with the jet of steam or spray of water to form sulphuric acid and condenses on the pan-like floors of the chambers. The temperature is regulated so that this "chamber acid" is not allowed to become concentrated in the chamber for, if so, it would dissolve the nitrous fumes and prevent oxidation of more  $\text{SO}_2$ . If required to be concentrated it is therefore pumped back to the top of the Glovers tower, where it is concentrated by the heat of the sulphur dioxide, oxygen, and nitrogen from the pyrites burners.

The acid from the foot of the Glovers tower is purified by distillation in glass, fused silica, or, preferably, in platinum stills.

From the third leaden chamber a mixture of oxygen, nitrogen, nitric oxide and nitrogen peroxide passes. This is led up a tower, Gay Lussacs tower, packed with flints, to meet a descending flow of strong sulphuric acid, which dissolves the nitrogen oxides. This is then pumped to the top of the Glovers tower, where it mingles with the chamber acid and descends.

For many commercial purposes the chamber acid is sufficient. It has a specific gravity up to 1.6 and contains from 60–70 per cent of  $\text{H}_2\text{SO}_4$ .

The acid from the stills usually contains up to 95 per cent  $\text{H}_2\text{SO}_4$  of specific gravity 1.8. Any impurities can usually be removed by redistillation, but the residual water can only be removed by freezing and consequent crystallization of anhydrous 100 per cent sulphuric acid. This is, however, hardly a commercial article.

**The Contact Process.**—The contact process is again a means of oxidizing sulphur dioxide by means of atmospheric oxygen. The sulphur dioxide, after preparation in the pyrites burners, must be

purified, as many possible impurities, *e.g.* arsenic, and even dust, would quite prevent action on a commercial scale.

The purification is a fairly lengthy operation but briefly consists in steaming the gas at a high temperature, washing with water and then drying with strong sulphuric acid.

The pure sulphur dioxide, which is now cool, is mixed with air and passed into the contact chamber. This contains tubes with several perforated shelves. On the shelves is placed asbestos impregnated with finely divided platinum or ferric oxide. (Platinized asbestos is 50 per cent more efficient than ferric oxide and asbestos.) At the outset the chamber is heated to almost exactly 400° C. (when this temperature is reached no further heating is necessary), and the cool gas mixture is passed in. As it passes over the catalyst (impregnated asbestos) combination takes place with formation of sulphur trioxide and heat is evolved. This heat is more than sufficient to maintain a temperature of 400° C. and is kept under control by being made to raise the temperature of the incoming mixed gases, and their rate of entry is so regulated that no rise in temperature of the asbestos takes place. It should be noted that at temperatures very little below 400° C. combination will not take place between air and  $\text{SO}_2$ , whilst a very small increase above this temperature causes sulphur trioxide to break down into sulphur dioxide again.

Considerable difficulty has been experienced in effecting combination between sulphur trioxide (in bulk) and water, and the general practice is to dissolve the  $\text{SO}_3$  in either dilute or strong sulphuric acid. If strong acid is used it is diluted simultaneously with its absorption of  $\text{SO}_3$  unless fuming sulphuric acid (Nordhausen sulphuric acid) is required, in which case it continues to absorb  $\text{SO}_3$  until the required strength is reached.

**Properties of Concentrated Sulphuric Acid, 95-98 per cent.—**

Sulphuric acid is an oily liquid (oil of vitriol) 1.84 times as heavy as water. When pure it is quite colourless, though organic matter soon causes it to go brown. It combines with water in all proportions with great evolution of heat. Since the temperature attained is above the boiling point of water it must on no account be added to water as the water might boil so suddenly as to have the effect of an explosion.

Dilution should always be effected by adding water to the acid the high boiling point of which is not reached. Sulphuric acid has such an affinity for water that it is used as a drying agent, especially for gases. It is also used to extract the constituents of water from bodies which contain them.

It attacks most organic bodies (not paraffins), usually charring them, *e.g.* paper, cloth, skin, sugar, etc., and many metals, although curiously enough, the dilute acid has more action on metals than the strong. This seems to be because the sulphates of the metals are not soluble in concentrated sulphuric acid, whereas many of them are soluble in water. For the foregoing reason, although dilute sulphuric acid readily attacks and dissolves iron, strong sulphuric acid is without action upon it and therefore can be safely stored and transported in iron vessels.

The action of sulphuric acid on the skin and eyes is so well known that "vitriol throwing" with intent to disfigure is by no means uncommon.

**Uses of Sulphuric Acid.**—The uses of sulphuric acid are manifold and emphasized by its enormous consumption. Amongst its more important uses are : the manufacture of ammonium sulphate, the manufacture of nitric acid, of washing soda and sodium sulphate ; in the preparation of dyes, in bleaching, in the purification of paraffins, in the oil and fat and paper industries. Sulphuric acid is also used for cleaning iron in the tin plate and zinc plate (galvanizing) industries.

Many organic substances demand sulphuric acid in their manufacture, *e.g.* ether, and it is used in the preparation of many explosives (nitro glycerine, etc.).

Many of the salts of sulphuric acid are of commercial importance, and some of them occur naturally. Kieserite (natural magnesium sulphate) is used in the manufacture of Epsom salts. Gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) is a well-known rock which is gently heated in kilns for the production of Plaster of Paris ( $2 \text{CaSO}_4 \cdot \text{H}_2\text{O}$ ), a powder which, when mixed with water to a paste, sets very hard and with expansion; consequently sharp impressions (casts) can be obtained with it in moulds. It can also be used as a cement.

Gypsum itself, when exceptionally pure and "solid," is known as alabaster and used for statuettes, etc. Gypsum is used as a fertilizer.

Another important natural sulphate is kainite, which substance, like kieserite, is found in the Stassfurt deposits. Kainite is an important manure, and it is also used in the preparation of potassium sulphate.

Copper sulphate is an important artificial salt of sulphuric acid. It can be made by heating scrap copper, adding sulphur whilst still hot to form copper sulphide, and then oxygen of the air converts the sulphide into sulphate, which can be dissolved and crystallized from water.

Copper sulphate, or blue vitriol, is also made from copper pyrites and sulphuric acid.

Copper sulphate, or blue vitriol, is a blue crystalline glass-like (vitreous) body easily soluble in water. It is very astringent and used in medicine on that account. It is somewhat poisonous and used as a spray in agriculture and as a preservative (timber). Other uses include electroplating baths, and in the dyeing and cotton-printing trades.

Barium sulphate, or heavy spar, is a natural sulphate of very insoluble and refractory character. It is used in paint and for the preparation of barium compounds.

Sodium sulphate (Glaubers salts) is prepared by heating the mixed gases from pyrites burners (containing sulphur dioxide) over salt for several days, dissolving and crystallizing. It is also made from kieserite and in the preparation of washing soda (*q.v.*).

For ammonium sulphate see under PURIFICATION OF COAL GAS.

Zinc sulphate (white vitriol) is used in medicine. Green vitriol (copperas, iron sulphate, ferrous sulphate) exists in many natural waters. It can be made from pyrites + water and air, or from iron and sulphuric acid. It is used in cleaning paint, in dyeing, and in making ink.

**THE ALUMS.**—When a solution of a sulphate of a monovalent element is mixed in appropriate quantity with a solution of the sulphate of a trivalent metal and the whole allowed to crystallize, one substance, an alum, results, *e.g.* potassium sulphate ( $K_2SO_4$ ) and aluminium sulphate [ $Al_2(SO_4)_3$ ] gives potash alum or alum [ $K Al (SO_4)_2 \cdot 12H_2O$ ].

Ordinary alum is used as an astringent in medicine, *e.g.* a gargle, as a mordant in dyeing, *e.g.* Turkey red, in the manufacture of

paper and leather, and to harden gelatine. It is sometimes used in baking.

**SODIUM THIOSULPHATE** ( $\text{Na}_2\text{S}_2\text{O}_3$ ) is a sulphate in which one atom of oxygen has been replaced by sulphur. It is prepared by boiling sulphur with milk of lime and exposing the liquid to air, whereby calcium thiosulphate is produced. This is treated with washing soda and a solution of sodium thiosulphate results, which can be filtered off and crystallized. As explained previously chlorine is used as a bleach but if it be allowed to remain it rots the fabric. Sodium thiosulphate is used to remove the chlorine and prevent this (*i.e.* it is an antichlor).

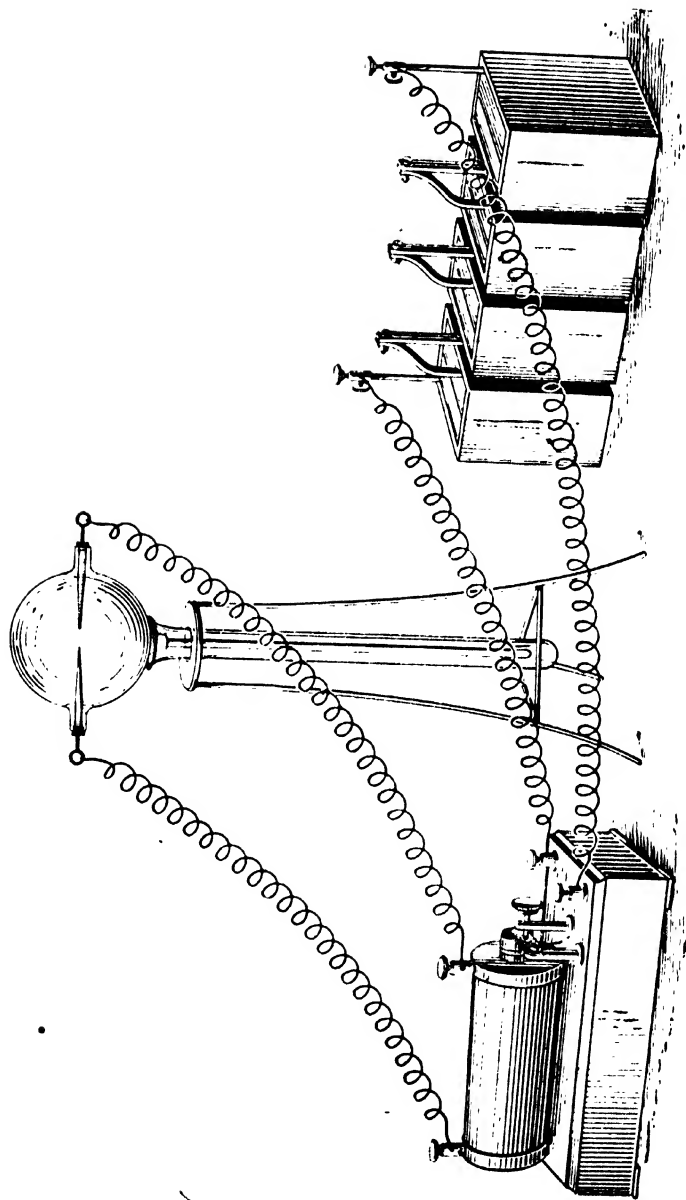
Sodium thiosulphate easily dissolves chloride, bromide, or iodide of silver, forming sodium silver thiosulphate ( $\text{NaAgS}_2\text{O}_3$ ). Now these substances are present in photographic plates and papers, and after the picture is taken and developed or printed would darken on exposure to light and cause the picture or negative to become indistinct. They are therefore dissolved out by a solution of sodium thiosulphate, or hypo, as the photographer wrongly calls it.

**SODIUM AND POTASSIUM PERSULPHATE.**—These substances are prepared by the electrolysis of strong solutions of sodium or potassium sulphates. They are much used as oxygen bleaches in laundering and cleaning and as reducers in photography.

**NITRIC ACID AND ITS SALTS.**—Nitric acid has been known from very early times, whilst in 1650 Glauber described one of the methods by which, in principle, it is manufactured at the present day. It is manufactured by heating together sodium nitrate (Chile saltpetre) with strong sulphuric acid in iron retorts. Nitric acid is at once produced, and since it boils at a lower temperature than sulphuric acid it distils off, leaving the higher boiling acid behind. It is condensed in worms and collected in earthenware jars.

Nitrogen peroxide is also produced in the reaction, some of which dissolves in the nitric acid, turning it yellow, whilst the remainder passes on into a coke packed tower and dissolves in the water which flows slowly down it. The crude acid is purified by redistillation and air or carbon dioxide is blown through to remove any dissolved nitrogen peroxide.

Fuming nitric acid is nitric acid containing dissolved nitrogen



NITRIC ACID FROM AIR

peroxide. It can be prepared by distilling nitric acid with a very little starch.

Nitric acid can be prepared from the air by causing the oxygen and nitrogen to burn together and then combining with water. The mechanism will be discussed under ARTIFICIAL MANURES. This method is carried on in Norway and Germany. A big attempt was made during the war to introduce it here in England, but the stony silence of the Government on the subject leads one to suspect that it has been a failure.

**Properties of Nitric Acid.**—Nitric Acid is, when pure, a colourless liquid which fumes when exposed to the air. It dissolves in water in all proportions with evolution of heat. It has a density of 1.56 and boils at 86° C., but the ordinary commercial concentrated acid has a density of 1.42 and boils at about 120° C.

Nitric acid turns skin, cloth, paper, etc., yellow, and then destroys them. It dissolves all metals except gold and platinum, and hence was called *aqua fortis*, but under certain conditions it causes iron to assume a "passive" state which does not dissolve, and it can then be contained in such iron vessels. It reacts with nearly all organic compounds, either oxidizing them or nitrating them.

**Uses of Nitric Acid.**—Nitric acid is used for the purpose of getting metals into solution and especially to separate metallic impurities from gold, which it does not dissolve. In general, nitrates of the metals are produced but sometimes oxides result.

Nitric acid is one of the most efficient oxidizing agents known, and it is used on an enormous scale for this purpose. Sawdust sometimes catches fire when introduced into nitric acid and oxalic acid is produced. Phthalic anhydride, an essential for the production of certain dyes and drugs, is produced by the action of nitric acid on naphthalene.

Nitric acid can be made to give, with alcohols, substances resembling salts. Thus, with ordinary alcohol and copper and nitric acid, ethyl nitrite ( $C_2H_5NO_2$ , sweet spirits of nitre), a valuable diuretic and heart accelerator is prepared.

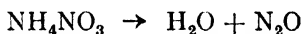
When glycerine is treated with nitric acid and the appropriate quantity of sulphuric acid to absorb water, glycerol trinitrate, or nitroglycerine, is produced. This substance is produced on an enormous scale. The nitric and sulphuric acids are first mixed in

a leaden vessel and then fine jets of very pure glycerine are blown in. The nitroglycerine is washed, filtered, and otherwise purified. It is a very powerful and uncertain explosive and therefore not safe to use, but when mixed with kieselguhr (a diatomaceous earth) it is called dynamite, or with other substances (*e.g.* nitroglycerine, guncotton, and paraffin make cordite) it is quite safe. Very many blasting and special explosives contain some nitroglycerine.

Nitroglycerine has an extraordinary action on the heart, and is used as a drug in cases of extreme cardiac collapse.

Ammonium nitrate, which is produced by the neutralization of nitric acid by ammonia, is a powerful explosive, going under various names. It is the chief constituent in Mills grenades and many other bombs.

When gently heated ammonium nitrate gives off a gas called nitrous oxide—



This gas causes anaesthesia with a curious loss of nervous control with return of consciousness. The patient often laughs hysterically, or cries, and hence the gas is known as laughing gas. It is much used by dentists.

**Sodium Nitrate** (Chile saltpetre, caliche) occurs naturally in vast quantities in Chile. It is a product of the Atacama desert and is exported mainly from Iquique. It is much used as a manure (especially for wheat) and in the preparation of nitric acid.

**Potassium Nitrate** (nitre or saltpetre) is also a naturally-occurring nitrate. It is found in the north of the Plain of Bengal. It is manufactured by the interaction of Stassfurt potassium chloride with Chile saltpetre.

It is a constituent of gunpowder, is often used in the reduction of ores to metals and as a preservative for meat (brine).

**Silver Nitrate** (lunar caustic) is prepared by dissolving silver in nitric acid and crystallizing the product. It is used medicinally for warts and other growths and areas giving pain.

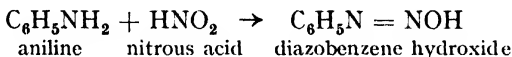
Most nitrates when heated give oxides, but sodium and potassium nitrates give sodium and potassium nitrite respectively—



Commercially, the nitrate is heated with lead.



These nitrites are of enormous importance in organic chemistry because they are the means of "diazotizing," a fundamental step in the manufacture of the enormously important azo-dyes. Thus—

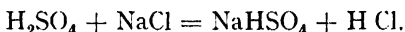


and diazo benzene hydroxide + phenol or cresol, etc., gives a red dye.

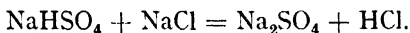
**HYDROCHLORIC ACID AND THE CHLORIDES.**—Hydrochloric acid (spirits of salt, muriatic acid, H Cl) was known to the Arabian alchemists. It occurs free on a very small scale in Nature, being found in volcanic areas and it is also present in the stomach.

Hydrochloric acid is prepared from its cheapest and most important salt (common salt, sodium chloride) and sulphuric acid.

A mixture of these two substances is heated in a pan. Hydrogen chloride is produced and sodium hydrogen sulphate remains—



The sodium hydrogen sulphate is heated (usually on the hearth of a reverberatory furnace) with more salt and a further yield of hydrogen chloride is obtained—



The sodium sulphate (salt cake) is an important intermediate product in the preparation of washing soda (*q.v.*).

The hydrogen chloride from the above two reactions is allowed to pass up towers or scrubbers packed with coke, and down which is a gentle flow of water. This dissolves the ascending gas and impure commercial hydrochloric acid collects at the bottom.

**Properties of Hydrochloric Acid and Hydrogen Chloride.**—

Hydrogen chloride is a colourless, pungent smelling, fuming acid gas much heavier than air and very easily soluble in water : 1 cc. of water at 20° C. will dissolve 440 cc. HCl. The aqueous solution (hydrochloric acid) is a strong acid. If it be boiled one of three things will happen : (a) If the solution contains 20·24 per cent HCl it will boil continuously at 110° C. ; (b) if the solution contains less than 20·24 per cent HCl, water will boil off at a temperature above 100° C. and gradually increasing to 110° C., and no higher, when 20·24 per cent of HCl will be present ; (c) if the solution contains

more than 20.24 per cent of hydrogen chloride  $\text{HCl}$  will boil off at temperatures below  $110^{\circ}\text{C}$ . and gradually rising up to it and no higher, by which time the solution will again contain 20.24 per cent of hydrogen chloride.

Ordinary commercial hydrochloric acid has a specific gravity of 1.160, and contains about 32 per cent of hydrogen chloride. Hydrochloric acid dissolves many metals, with formation of chlorides, and reacts with superoxygenated bodies, producing chlorine.

**Uses of Hydrochloric Acid.**—Hydrochloric acid is used in the preparation of chlorine, in bleaching with chlorine (see Bleaching Powder), in dyeing and cotton printing. It is used for cleaning iron prior to tinning and galvanizing and in many chemical industries.

**Chlorides.**—The salts of hydrochloric acid are called chlorides, and the most important of these, in fact, after coal, iron, and water, probably the most important of all minerals, is sodium chloride, or common salt.

Salt has been known and used from the very earliest times as an essential food. It is said that all human beings, however low in the scale of civilization, eat salt unless they consume raw blood, which contains it, whilst many animals, especially herbivorae, are extremely fond of it.

In districts which do not possess salt, *e.g.* parts of Central Africa, it is an important commodity, forming one of the principal objects of trade. Salt was a part of the Roman soldiers' pay, hence the word "salary," and we still speak of a worthless man as not worth his salt.

**Occurrence.**—Salt is the chief solid constituent of all sea water, which contains up to about  $2\frac{1}{2}$  per cent of salt. The Saxons called a place where salt was mined a wych, and many wyches are still important sources of salt in England to-day, *e.g.* Nantwich, Northwich, Middlewich, and Droitwich. Salt is very widely distributed, and other commercial supplies come from Wieliczka (near Cracow), Stassfurt (Saxony), Cardona (Spain), California, Utah, New York, the Punjab, Chile, Peru, and very many other places.

The Wieliczka mines deserve special mention. The salt beds have a thickness of 1,200 ft. and an area of nearly 10,000 sq. miles. They have been mined for nearly 800 years.

There are eight levels, many lakes, chapels, a stud and stables,

statues, a ball-room, a railway station and 25 miles of track. The output is about 60,000 tons of salt per annum. This is small compared with England, which produces 2,000,000 tons, involving one-fifth of a cubic mile, every year. Cheshire alone produces 1,500,000 tons!

**Manufacture of Salt.**—Salt is extracted from sea water in hot and in cold countries, *e.g.* the Mediterranean and White Seas. In hot countries evaporation is carried out by the sun, the brine being contained in tanks which can be filled at high tide. Sometimes, as in Japan, sea-weed fires assist evaporation. When sea water freezes it does so from the bottom at a temperature of about  $-2.8^{\circ}\text{C}$ . The ice produced at once rises to the surface and it contains practically no salt. If, therefore, a limited quantity of sea water be partly frozen the residual liquid will contain all the salt in a much more concentrated condition. This fact is made use of on the White Sea and the final evaporation is effected by a fire.

Salt exists naturally either in massive crystalline condition (rock salt), in solution, or in small-crystal deposits (the Colorado field, near Salton, where salt is steam-ploughed).

In England salt is chiefly mined from subterranean brine which is pumped to the surface. Even when the salt exists in the solid state it is usually dissolved in situ, the solution collected in a sump and pumped to the surface. At Wieliczka it is cut out and brought to the surface in masses. It is then made into brine above ground. In order to economize fuel the wind is sometimes made to aid evaporation and a big surface presented by making the brine flow over brushwood.

In England, however, this is not done. It is well known that the slower the evaporation the larger the crystals, and this is taken advantage of in the industry. Thus, salt for the table, where small crystals are required, is produced by very rapid evaporation at about  $107^{\circ}\text{C}$ ., whilst cooking salt, salt for preserving fish (fish salt), etc., are evaporated at much lower temperatures, correspondingly larger crystals being produced.

Some of the common impurities in salt are hygroscopic, *e.g.* magnesium chloride. These mostly remain in the mother liquor, but can be finally removed by redissolving the salt and precipitating it by the addition of gaseous hydrogen chloride.

**Properties.**—Salt is a white cubically crystalline solid, soluble in water, 36 grams per 100 cc. at 15° C., 39 grams per 100 cc. at 100° C. It melts at about 800° C. and is very stable. It is a germicide.

**Uses.**—Salt is an essential food. It is used as a preservative for meat, fish, and vegetables. It is the fundamental ingredient in the washing soda, alkali, and soap industries. It is used in the manufacture of hydrochloric acid and all chlorine and sodium compounds, of glass and pottery glaze, and many other industries. It has latterly been argued that injections of salt water are of pronounced therapeutic value.

**Potassium Chloride** is found naturally at Stassfurt in sylvine (KCl) and in carnallite ( $\text{MgCl}_2$ , KCl, 6  $\text{H}_2\text{O}$ ). It is obtained chiefly by digesting carnallite in mother liquor and heating the liquid. The potassium chloride dissolves but the associated bodies do not. The solution is decanted and crystallized and the crystals purified by washing and recrystallization. The mother liquors are used over again.

Potassium chloride is cubically crystalline like salt, than which it is rather less soluble in water. It is used as a manure, for the preparation of other potassium salts, *e.g.* caustic potash, and in other ways.

**Silver Chloride**, made from silver nitrate and salt, is used in photographic papers.

**Copper Chloride** is used in the Deacon process for chlorine.

**Ammonium Chloride** (sal ammoniac) is made on a very large scale from ammonia and hydrochloric acid. Ammonia from the scrubbers of coal gas is mixed with hydrochloric acid and the solution allowed to crystallize. It can be purified by sublimation. It is used in Leclanché cells (for electric bells) in dyeing and cotton printing, as a flux for solder, and medicinally.

**Zinc Chloride** is used as a flux for solder. It is the substance produced in solution when the tinman "kills" spirit, *i.e.* he dissolves zinc in hydrochloric acid with evolution of hydrogen and production of zinc chloride.

**Gold Chloride** ( $\text{AuCl}_3$ ) is used for toning ordinary printing-out paper; it is used in the preparation of self-toning paper. Gold chloride is produced in the chlorine extraction of gold.

Organic bases form chlorides and hydrochlorides, many of which, *e.g.* methylamine hydrochloride, are of great use in the dyeing industry, whilst the hydrochloride of quinine is a well known drug.

The acid chlorides, *e.g.* benzoyl chloride, are used on a commercial scale in a great many organic preparations.

**Phosphoric Acid and the Phosphates.**—Some phosphates are used medicinally and others as manures. The manures will be dealt with in the chapter with that heading.

**BORIC ACID AND BORAX.**—The marshes of Tuscany have jets of steam (soffioni) issuing from fumaroles. This steam contains a small percentage of boric acid. When the steam condenses to form small lagoons the boric acid dissolves in the water of the lagoon. The yield has been increased by constructing artificial lagoons and artificial borings for steam.

The water of the lagoons is evaporated in tanks, the natural steam serving as fuel.

Boric acid is also obtained from borates which exist in solution in California and Nevada. The crude acid is purified by boiling with animal charcoal and recrystallization.

Boric acid ( $\text{H}_3\text{BO}_3$ ), which is the same as boracic acid, consists of pearly-white leafy crystals soluble in water. It is used as a non-irritant antiseptic, as a preservative (·5 per cent can be used in cream) in milk, and also in sausages, etc. Boric acid should not be used in milk or cream for babies or invalids. Borax is prepared from boric acid.

None of the true borates is of much importance, but borax, sodium pyroborate ( $\text{Na}_2\text{B}_4\text{O}_7, 10 \text{H}_2\text{O}$ ) is of very great use. It occurs native, under the name of tincal, in Tibet, and also in California, but these supplies are not enough and it is made from Tuscan boric acid by treatment of its solution with washing soda solution and crystallizing from the mixture. It is also made from natural calcium borate (boro natrocalcite) by boiling with washing soda solution.

Borax is a white crystalline solid. When heated it first swells up (intumesces) and then goes into a clear molten mass, which dissolves many metallic oxides, producing such characteristic colours as to form a most important test for the metals. Further, since it dissolves metallic oxides it will remove oxide tarnish from

the surface of metals, leaving a bright metallic surface. Hence it is used in brazing, soldering, and other processes where a bright metal is required.

Borax is used in making enamel, pottery glaze, and glass (optical). It is sometimes used as a preservative for food but it is doubtful whether it is exactly beneficial to the consumer. It is sometimes used as a dressing for small wounds and sores, being somewhat antiseptic.

Borax has detergent qualities and is used in making special varieties of soap, and it is also used as a substitute for starch in the laundry in certain cases. Borax is also used in some varnishes and paints.

**HYDROFLUORIC ACID** ( $\text{HF}$ ).—Hydrofluoric acid is prepared by heating pure crushed fluor spar (calcium fluoride,  $\text{CaF}_2$ ) with strong sulphuric acid in cast iron retorts. Hydrogen fluoride gas is evolved and collected in leaden vessels containing water, which dissolves the gas. The solution is stored and marketed in wax or gutta percha (sometimes lead) bottles. Hydrofluoric acid is poisonous to inhale or to the skin. It dissolves many metals, minerals containing silica, *e.g.* flints, and silicates such as glass. Its chief use is in being made to dissolve some glass and leave the remainder, *i.e.* to etch it. This is done by covering the glass with wax (which the acid does not dissolve) and drawing the required design in the wax so as to expose the glass. This is then either washed with the acid or acted upon by its vapour, and after dissolving off the wax in turpentine the design remains. There are many natural fluorides, of which fluor apatite is used in preparing phosphorus and fluor spar (calcium fluoride) in preparing hydrofluoric acid.

**Cryolite** (sodium aluminium fluoride,  $\text{Na}_3\text{AlF}_6$ ) is found in Greenland as a white vitreous crystalline solid. It can also be made artificially. It is much used as a flux, especially to dissolve alumina (bauxite) in the preparation of aluminium in the electric furnace.

**CARBONIC ACID AND THE CARBONATES.**—The enormous number of acids containing carbon are part of the subject matter of organic chemistry, but it is usual to consider one (carbonic acid) as of mineral origin, since itself it occurs in non-living matter and

some of its salts form important rocks, although in very many cases these rocks had an organic origin.

The acid is a comparatively weak solution of its anhydride, carbon dioxide, and since this is given off in vast quantity by volcanoes and burning fuel, and wherever heat or acid acts upon carbonate rocks, it is to be expected that most surface water and most underground water is a solution of carbon dioxide, *i.e.* is carbonic acid.

Carbon dioxide has been known but not clearly distinguished from very early times.

**Occurrence.**—Carbon dioxide forms about .03 per cent of ordinary air in the free state. It is present in sea water, and wherever coal, oil, or wood burns. The chief rocks which are carbonates include chalk, limestone, marble, Iceland spar, stalagmites, stalactites, and coral, which are all calcium carbonate, dolomite, which is calcium, and magnesium carbonate in about equal parts (the Dolomite Alps), malachite (copper carbonate), clay ironstone, and blackband ironstone (iron carbonates, etc.), magnesite (magnesium carbonate). Much water contains calcium bicarbonate in solution.

**Manufacture.**—Carbon dioxide is produced when chalk is burnt to make lime, but is then allowed to escape as of no importance. Sometimes, however, specially constructed kilns are used in which chalk or magnesite is burned and the carbon dioxide gas evolved washed and dried. When yeast grows and ferments sugar, etc., carbon dioxide is produced, and this is sometimes collected at the breweries.

The gas, however collected, is stored under pressure in iron cylinders when it, as a rule, liquefies. When the pressure is released the liquid evaporates and the cylinder delivers solid carbon dioxide and gaseous carbon dioxide.

**Manufacture of Mineral Waters (Aerated Waters).**—Mineral water was at first a term applied to natural supplies of water rich, or fairly rich, in dissolved substance and sometimes with an excess of carbon dioxide (such as Apollinaris and Hunyadi Janos). Artificial mineral water usually consists of super-saturated solutions of carbon dioxide and small quantities of dissolved sodium carbonate or flavoured syrup.

The carbon dioxide derived from the liquid ( $\text{CO}_2$ ) stored in

cylinders is allowed to pass into a vessel with a fine spray of water. This solution is then forced into bottles containing a little sodium carbonate solution, if soda water is being prepared, or fruit syrup if other mineral waters are being manufactured. The air originally in the bottle is forced out of a valve, and the bottles are then closed by screw stoppers or marbles. The pressure in the bottles is usually about 3 atmospheres. Infusions of soap bark (*quillaia* bark) are sometimes added to mineral waters in order to give them a nice frothy head.

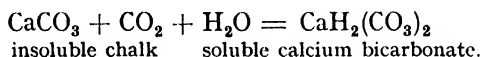
Brewed ginger beer (stone ginger) is made by fermentation, and is not a mineral water but a beer. A sugar solution flavoured with ginger essence and citric acid is fermented by yeast and bottled usually, when about 1 per cent of alcohol has been produced, although sometimes the yield of this substance is much more, and cases of intoxication by ginger beer, although this sounds rather like an ingenious plea, are not infrequent. A ginger beer can be prepared direct from honey without yeast.

**Properties of Carbon Dioxide.**—Carbon dioxide is a colourless, slightly acid gas much heavier than air. It is so heavy that it flows like water and collects in hollows and old wells. It extinguishes a flame, and if inhaled causes suffocation. Certain natural and historic phenomena are due to this cause. For instance, the well-known Dog's Grotto of Naples is explained by the fact that the cave has a depressed floor and that depression is always full of carbon dioxide which enters through fissures in the rock and then, after filling the basin, rolls away. The depth of the hollow is greater than the height of a dog but less than that of a man. When a man and dog enter, therefore, the man is breathing air but the dog is in an atmosphere of carbon dioxide and is suffocated. Unfortunately for romance the celebrated sentry at Pompeii was probably unconsciously suffocated by a flow of carbon dioxide down the side of Vesuvius and was only buried in lava after he was dead. Tramps are often suffocated by carbon dioxide when they sleep at the feet of lime kilns for the warmth, and entry into old wells and mines, and mines after explosion, is dangerous because of the possible presence of carbon dioxide gas (choke damp).

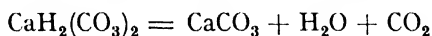
A solution of carbon dioxide (carbonic acid) can dissolve chalk



to form calcium bicarbonate and thus water in chalky districts usually contains that substance—



When such a solution is boiled the calcium bicarbonate is broken up and the insoluble chalk is again deposited—



This is the cause of “fur” in the kettle, etc., and boiler scale. Scale is very objectionable as it entails a great wastage of heat and, especially in tubular boilers, its removal is expensive. Chalky water is therefore often softened before use by the addition of the calculated quantity of slaked lime which converts all the bicarbonate into carbonate and precipitates it—



The chalk is allowed to settle and the softened water drawn off. Scale is to some extent prevented by putting special substances in the boiler.

The fact that carbon dioxide extinguishes a flame is made use of in fire extinguishers. These usually contain a carbonate (sodium carbonate) and sulphuric acid. The sulphuric acid is contained in a thin glass vessel which, when knocked, is broken, the acid flows on to the carbonate, and carbon dioxide is liberated, which can be directed at any part of the fire.

**COMMERCIALLY IMPORTANT CARBONATES.**—**Sodium Carbonate or Washing Soda.**—This substance occurs naturally in the alkali deserts of the Rocky Mountains, in Owen’s Lake, California, in Egypt, in the Rift Valley of British E. Africa, at Magadi, and other places. Natural sodium carbonate is known in various localities as natron urao or trona.

These natural soda deposits are sometimes of great purity and on ignition yield up to 99 per cent soda. The ash of sea plants contains sodium carbonate.

Vast quantities of sodium carbonate are prepared artificially from salt. This is first of all converted into sodium sulphate (salt cake) as already described. The salt cake is then mixed with small lumps of limestone or chalk and a good fine coal in the approximate

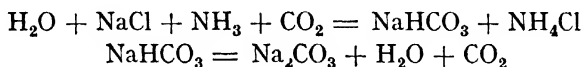
proportions of 2 of salt cake and 2 of calcium carbonate to 1 of coal. This mixture is heated in a special furnace, with constant mixing by revolution, until the mass first melts and then becomes pasty. The carbon probably reduces the sodium sulphate to sodium sulphide, and this reacts with the calcium carbonate, producing sodium carbonate and calcium sulphide. Carbon dioxide is evolved. The result of this reaction is *black ash*, a brown-black solid containing up to 45 per cent of sodium carbonate. The ash is powdered and put in tanks, into which water passes. It is usual to have one tank of fresh black ash to two or three of partially extracted ash. Water is passed first into the tank containing the most completely extracted ash, then to the next, and finally to the fresh made ash. The time to change the water is shown by a hydrometer measuring the density of the solution, and as soon as the ash in one vat is completely exhausted it is removed and fresh ash added. The whole of this process should be carried out as quickly and yet at as low a temperature as possible. It is called the *lixiviation* of the black ash.

The solution of sodium carbonate is now evaporated to dryness and the resulting soda ash further roasted in air to oxidize any contained sulphide. It may now be put on the market as 58 per cent alkali, but will possibly be crystallized from water and crystals of washing soda ( $\text{Na}_2\text{CO}_3 \cdot 10 \text{H}_2\text{O}$ ) obtained.

The solid left in the tanks consists of calcium sulphide, coke, etc. It may be dried, powdered, mixed with water and carbon dioxide passed through. Chalk is precipitated and sulphuretted hydrogen produced. This gas is mixed with a limited quantity of air and heated with iron oxide. The hydrogen burns to form water, and sulphur is produced which melts and is collected and used, chiefly in the manufacture of sulphuric acid. Sometimes the calcium sulphide in the tank waste is oxidized with air for the preparation of "hypo."

**The Ammonia Soda Process** (Solvay's method).—This again is a method for preparing washing soda from salt. The salt used is usually in the form of brine pumped directly at the factory to save transport charges. The brine is allowed to trickle down a tower up which ammonia gas ascends and so becomes saturated with ammonia. This ammoniacal brine is allowed to settle as some of

the impurities present in the natural brine pass to the bottom and are got rid of. After getting sufficiently cool it is pumped into a tower with perforated shelves, into the bottom of which carbon dioxide (partly derived from a lime kiln and partly from sodium bicarbonate produced as an intermediate in the process) is forced. The mixture interacts with the formation of crystals of sodium bicarbonate, which collect on the shelves, and ammonium chloride. The crystals of bicarbonate are collected, washed, and heated, whereby sodium carbonate is produced—



The ammonium chloride solution is crystallized, mixed with the lime from the kiln, and the ammonia required thus generated—



**Sodium Carbonate** is a white crystalline solid easily soluble in water. The crystals are efflorescent, *i.e.* give up water, on exposure to the air. The solution is alkaline and has a strong detergent action. With acids sodium carbonate, like all other carbonates, gives carbon dioxide gas.

Sodium carbonate is used in cleaning all kinds of textiles and in scouring generally; in preparing glass and in a very large number of chemical processes.

**Sodium Bicarbonate**, or cooking soda, which is an intermediate product in the Solvay process, is a white powder which gives off carbon dioxide below 100° C, in solution or by itself. Hence it is used in cooking as a substitute for yeast. It is used also in cooking green vegetables in an alkaline solution so that they shall have a good colour. In this case it is used because it furnishes pure sodium carbonate on boiling. It is used medicinally as a cure for indigestion, and in Seidlitz powders, sherbet, baking powder, etc.

**Potassium Carbonate** is present in wood ashes which are steeped in water and the lye used as soap. The word "potash" is derived from this method of preparation.

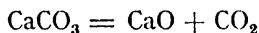
Potassium carbonate can be prepared by the Le Blanc soda process, starting from potassium chloride instead of salt, and also

from carnallite and washing soda. Potassium carbonate, like sodium carbonate, can also be produced by the Castner electrolytic process; it cannot, however, be manufactured by the Solvay process since potassium bicarbonate is too soluble to settle on the shelves.

The properties of potassium carbonate are similar to those of sodium carbonate. It is, however, more expensive, especially in England, which possesses much salt but little potash, and therefore is not so extensively used. As a plant food, however, it cannot be substituted by sodium carbonate. It is because potassium carbonate is an essential plant food that gardeners throw their "bonfire" ashes on the soil.

**CALCIUM CARBONATE.**—Calcium carbonate exists naturally in many forms as chalk, marble, stalactites and stalagmites, shells, Iceland spar, limestone, calcite, and coral, and, in combination with magnesium carbonate, as dolomite.

Marble and limestone are quarried for decorative and constructional stonework. Chalk and limestone are also obtained for the manufacture of lime. The limestone is cut into blocks and charged into a brick or limestone "kiln," usually in alternate layers with coal, although an increasing modern practice is loosely to fill the kiln with limestone and burn producer gas at the bottom in order to provide the heat. When the action is adjudged completed, or the coal-fire goes out, the quicklime produced is taken out—



**Quicklime** (or calcium oxide) is a white solid which becomes incandescent when strongly heated (limelight). When water is added, it almost instantly becomes very hot, swells up, and crumbles, slaked lime (calcium hydroxide) being formed. Slaked lime is somewhat soluble in water (lime water) and the solution is alkaline.

Quicklime is used in making mortar. It is first slaked and then mixed with varying quantities of sharp sand to a paste. This on exposure to the air loses water, absorbs carbon dioxide, and becomes a hard white solid. Lime is also a constituent of building cement.

**Portland Cement** is made by mixing together chalk and an appropriate clay (that found in the Medway is excellent for the

purpose) and grinding it very finely indeed in a tube mill, somewhat similar to that used for quartz gold ores. This fine floury powder is then fed into the top of a long inclined revolving cylinder at the bottom of which is a coal-dust fire so agitated by a fan as to burn very violently. As the powder passes down the tube (which is about 6 ft. in diameter) it becomes hotter, until by the time it has been in contact with the flame itself it has burnt to rather large nodules, like clinkers. These are cement. The nodules are then ground to powder in a tube mill and marketed.

Portland cement is, at present and for want of more knowledge, best regarded as a solid solution of three chief substances: lime, aluminium oxide, and silicon oxide (sand or quartz). As is well known, Portland cement, when made into a paste with water, soon sets hard. The reason is not known, although it is supposed that a calcium aluminium silicate in the colloidal state is first formed which gradually deposits crystals of calcium aluminate. Other colloids (substances which will not pass through a semi-permeable membrane) are also present, and these also tend to become crystalloids by loss of water, and as this change takes place the cement becomes increasingly hard. (It should be added that there is no convincing proof of this.)

Many other cements have been devised merely for some special purpose, as, for instance, quick-setting for use under tidal water, etc., but they are in many cases similar to the foregoing.

A good Portland cement should have a tensile breaking strain of at least 400 lb. to the square inch one week after mixing with water and 500 lb. to the square inch four weeks after mixing with water.

**Plaster of Paris** is used in many cases, particularly for internal work, as a cement. In one particular case it is heated, then mixed with borax and cream of tartar solutions, heated again and ground. This is called Keene's cement.

To return to the uses of lime, it is a very valuable fertilizer and the cheapest medium for drying gases. For this last purpose it is used in enormous quantities at the gas works. Slaked lime is used in the manufacture of bleaching powder, and lime is also used in preparing ammonia (see the Solvay process). Calcium carbide, used as a source of acetylene gas and in the preparation of nitrolim

(see manures) is also prepared from lime. Lime is also used in the preparation of artificial calcium nitrate and in the manufacture of glass.

**Ammonium Carbonate** (lump ammonia) is used in the preparation of sal volatile and for cleaning purposes, and in the preparation of very light pastry. It can be prepared from ammonia and carbon dioxide. It is a white volatile alkaline solid smelling strongly of ammonia.

**AMMONIA GAS.**—Ammonia gas is prepared on a very large scale by the distillation of coal. The gas which first comes off contains much ammonia, which is removed by solution in water in scrubbers.

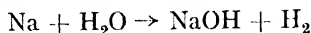
Ammonia is an alkaline gas, colourless, and with a strong pungent smell. It is extremely soluble in water. The solution is lighter than water, the strongest made having a density of .880. It is usually spoken of as 880 ammonia. Ammonia is easily liquefied.

Ammonia is used in the ammonio soda process and in the preparation of sal ammoniac. It is an ingredient in many general cleaning and scouring agents, and in some plate polishes, since it dissolves grease. Liquid ammonia is used in refrigerating machines.

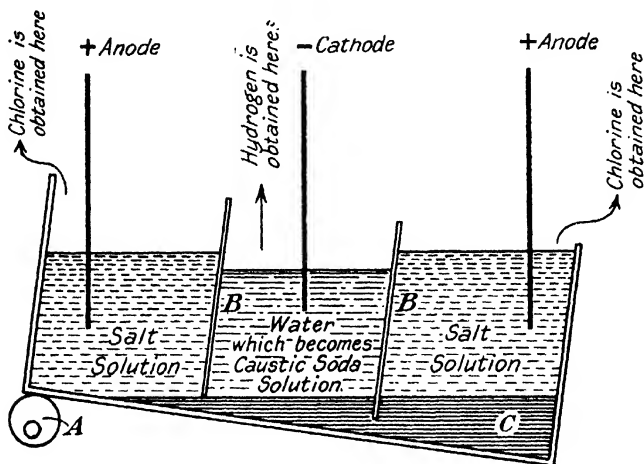
Ammonia has been known for centuries. The name itself seems to be derived from Ra Ammon, the great Egyptian god, and so ammonia was evidently familiar to the Egyptian priests, possibly because camel dung is a typical desert fuel, and ammonium salts are present in the fumes from a camel-dung fire.

**CAUSTIC SODA.**—Caustic soda is prepared from salt by electrolysis. A large slate tank is divided into three compartments, but the two intermediate divisions do not reach the floor of the tank. The compartments are rendered self-contained by a layer of mercury or fused lead. The tank is made to rock on an eccentric. Brine is introduced into the two outer compartments and water into the centre. When a current is passed, ions from the salt in solution (which is broken up into  $\text{Na}^+$  and  $\text{Cl}^-$ ) travel, chlorine towards the anode, and sodions towards the cathode. The chlorine, when it gives up its charge, passes through the exit pipes to storage cylinders, and this is an important commercial source of the gas. The sodium dissolves in the mercury and passes into the cathode

compartment where it gives up its charge and attacks the water, forming caustic soda and hydrogen—



The hydrogen can be made to combine with the chlorine to produce hydrogen chloride if desired, or it may be used to spark with atmospheric nitrogen with an osmium catalyte to produce ammonia, or it may be stored as hydrogen.



*A* = eccentric rocker.

*B* = partitions which do not reach to bottom of tank.

*C* = layer of mercury which just closes tank into 3 compartments.

#### CAUSTIC SODA MANUFACTURE BY ELECTROLYSIS

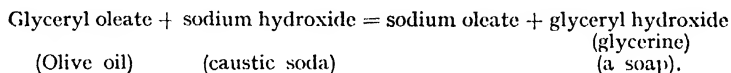
The caustic soda solution in the centre compartment is withdrawn and evaporated to dryness. The caustic soda left is fused and cast into sticks or broken up.

Caustic soda is a white deliquescent solid which rapidly absorbs carbon dioxide from the air. It should therefore be kept airtight. It is strongly alkaline, easily soluble in water in practically all proportions, and easily fusible. It attacks glass and porcelain when hot, and is best used in nickel or silver apparatus. It is strongly detergent and attacks wool and silk. Caustic soda decomposes fats, forming the sodium salt of the particular acid and an alcohol.

**Use of Caustic Soda.**—Caustic soda is used in many chemical industries and processes, in bleaching, dyeing, and in mercerizing

cotton. • It is used on an enormous scale in the production of soap.

Theoretically the formation of soap consists in the decomposition of a fat to form a sodium salt of a fatty acid (which is soap) and glycerine. Thus—



**Manufacture.**—Beef and mutton fat, palm oil, olive oil, coconut oil, etc., are melted in huge vats and pumped into big boilers, which are heated by super-heated steam entering through perforated coiled pipes. Weak caustic soda solution is also run in and the whole boiled up together. The action indicated above soon takes place, and then salt is added to make a brine on which the soap will float. After settling, the liquid which contains the glycerine is run out and the residue again boiled up with caustic soda solution. (Any fat left after this operation is used in the manufacture of dog biscuits.) The soap is now boiled up with water until it gets the required consistency, after which it is given some time to settle. Two layers of soaps are formed, the lighter being the better quality. The top soap is then removed, cooled, and compressed into moulds or cut into bars by means of wires. The heavier inferior soap, “nigre,” is worked up with fresh and poorer quality fats to form a non-toilet soap. High grade toilet soaps are sometimes purified by boiling up with alcohol or glycerine and rolling; inferior soaps can be made transparent by sugar syrup.

The glycerine in the lye is recovered by filtration and evaporation in vacuo, *i.e.* at a low temperature. A strong solution of glycerine (80 per cent) is thus obtained, which can be successively distilled and redistilled in vacuo until the required degree of purity is attained.

Soft soaps may consist of potassium stearate, etc., and fish oils as well as cotton-seed and colza oils are used.

It should be stated that a tremendous amount of research is going on in the soap industry and important changes in procedure are constantly taking place.



Free caustic soda should not be present in a good soap, and further, a good soap should not contain much water, although ingenious manufacturers sometimes contrive to put as much as 40 per cent of water into soap. Manufacturers should be compelled to furnish the percentage of water and free alkali in all soaps.

**Potassium Hydroxide**, which can be prepared by the electrolysis of fused potassium chloride or by Castner's process, has properties similar to those of sodium hydroxide. It is used in the preparation of soft soap and in many chemical, dyeing, and bleaching processes.

## CHAPTER X

### FUEL AND FUEL PRODUCTS

THE particular fuel which is used in any area is that one which is most easily available and most suitable at the price. Thus in deserts dried dung, especially camel dung, is the usual fuel. In the frozen regions seal and whale oil are most used. Following certain oil strikes natural gas has been used on an extensive scale in the region of the wells. In the Russian and Siberian forests wood is almost the only fuel. On the lower Volga the steamers carry loads of oil waste, and on the Nile attempts have been made to use the Nile sudd. The highland peasant uses peat, whilst throughout large sections of the world coal and mineral oil and coal-gas are chiefly used. Even water is now used in highland regions of high rainfall as the "fuel" which generates electricity, whilst the foundryman uses coke and the Sicilian sulphur manufacturer burns sulphur.

**PEAT.**—Peat is formed by the bacterial decomposition of vegetation at moderate temperatures. It does not form in the tropics since complete decomposition takes place there before peat can form. It is cut in Ireland, Scotland, Norway, etc. The peats, which usually are a mere surface layer resting on rock, are cut out by hand, or in a few cases by a special machine, and stacked to dry.

Peat is used as domestic fuel, for smoking bacon, for the production of various types of water-gas, and it is distilled for its oil products. Peat is used for other purposes than as a fuel, *e.g.* in the manufacture of blankets, wadding, etc., and in the preparation of special soils.

**COAL.**—In the carboniferous ages giant club mosses, *auracariās* (monkey-puzzlers) and ferns in the high temperatures then prevailing, and in the basin-like swamps favourable to their growth, converted the carbon dioxide, which then formed a larger percentage of the atmosphere than it does now, into organic (carbonaceous) matter and into oxygen. This more than luxuriant vegetation died, descended into the swamp mud, and whether by heat or compression, or both, became converted into the fossil

high carbon content substance which we call coal. The coal measures usually overlie millstone grit and are often covered by chalk, whilst the total thickness of the coal-bearing strata may be as much as, for instance in S. Wales, 12,000 ft. Individual seams of coal may be as thick as 40 ft. or as thin as one inch, and there will be a great many in a field. Of course, in any field, the thick seams near the surface are the first to be worked, the mines gradually getting deeper and the seams getting thinner as the coal gets exhausted. In Britain mines go down to 3,000 ft., probably in the future to 5,000 ft., and seams of rather less than 2 ft. thickness are worked, whilst the Royal Commission on Coal included as possible sources of supply all seams down to 1 ft. in thickness. A coal seam may sometimes extend throughout a whole field.

**Occurrence.**—Coal measures are known to underlie more than 500,000 square miles of the earth's surface. Enormous deposits occur in the middle Yangtze basin in China, from Pennsylvania to Alabama in U.S.A., and in the neighbourhood of the Crows Nest Pass in Canada. Japan, India, Siberia, Spitzbergen, and New South Wales all have large resources. In Europe the largest known deposits are in the Dombrovo coalfield of Poland, in the Ruhr basin of Germany (Essen, etc.), in the north of the central tableland of Spain, in the north of France and southern Belgium (Mons and Lille), in the Campine, and in Yorkshire, Durham, South Wales, the Clyde, North and South Staffordshire, Leicestershire, Fife, etc., and Kent in the United Kingdom.

The position of coal is found by geological borings so as to get a complete survey of an area. This has as yet been very imperfectly done, and it is almost certain that with increased geological survey new fields will be discovered and the extent of known fields will be very greatly increased.

**Extraction.**—In certain favoured areas, as Marco Polo wrote many centuries ago, certain black stones were dug out of the mountain side which burned like wood and gave considerable heat. Mining of this kind is still carried out in China, where children just burrow into the mountain side, filling baskets with coal as they go. In America the coal is usually mined without shafts by following the seam from the outcrop; but generally speaking, however, the coal measures have to be reached by shafts, and these nowadays

are nearly always of circular section and brick-lined. In the United Kingdom there must be at least two shafts to each mine, more than 15 yards apart, connected together and both fitted with serviceable winding gear. As a rule one of these is only used as a ventilating shaft.

In actually getting the coal either roads (stalls) are driven through the coal, and cross roads, as it were, driven from road to road, or else the whole of the coal is systematically cleared away from near the shaft and proceeding outwards. The space cleared is partly filled with the rubbish (goaf). In either case extensive timbering is necessary to support the roof and prevent subsidence.

The second, or long wall, system is usually adopted for thin seams, and the former, which necessitates leaving pillars of coal to support the roof (pillar and stall system) is used in thick seams.

Formerly, after a hole had been cut beneath the coal with a pick it was wedged out, but now the electric drill bores holes for mechanical expanding wedges or else the coal is blasted out. Special blasting cartridges are used which emit steam and thus prevent a flame, which might otherwise cause an explosion by igniting gas or coal dust in the mine. In America the compressed air cutter is used with very good results, but the British miner is too prejudiced to view its use with favour.

The miner works with a boy (putter) who loads the coal into baskets and pushes them to the tramway. The tramway may take the form of tubs on a continuous band which keep moving at a walking pace.

Especial difficulties in mining are subsidence, prevented by timbering; flooding, prevented by drainage and pumping; and gas. The gas is mainly of two kinds, fire-damp or methane, which is light, burns, and can form an explosive mixture with air, and carbon dioxide, or choke damp.

Sometimes, following a marsh-gas explosion in the limited air supply of the mine, the highly poisonous carbon monoxide is produced, but generally carbon dioxide is formed by the ignition of methane. Carbon dioxide (choke damp), a suffocating gas when in fair quantity, is also liable to be present in the ordinary way (see p. 107) especially as the coal measures are often overlaid by chalk or other carbonate rock. Coal dust itself is explosive.

**Kinds of Coal.**—A very regular gradation of properties is recognizable from fresh vegetation (wood), to peat through lignite (brown coal), to bituminous coal, anthracite, and perhaps even graphite.

As we pass through this series we get a fuel which has a greatly increasing quantity of carbon (in non-volatile form) and a greatly decreasing quantity of water and other volatile matter.

*Lignite*, which is very nearly allied to the darkest kinds of peat, burns well, but has only about half the calorific value of ordinary coal, and more ash. It rarely pays for transport, but can be used profitably near its source, *e.g.* in the beet sugar refineries in and near Leipzig.

*Bituminous coal* is harder and denser than lignite, and does not burn with so smoky a flame. Certain bituminous coals, *e.g.* those of Durham and Gelsenkirchen, when heated cake together. These coals are known as "coking" coals, and are used for the preparation of metallurgical or foundry coke, being able to support the weight of crucibles, etc., when used as a fuel for them without other aid and without crushing. Such coke is also used in blast furnaces.

*Cannel coals* are a special variety of bituminous coal which burn with a candle-like flame (long, luminous, and smoky) and so have earned their name, which is a corruption of candle. Cannel coals crackle violently when heated. They are used almost exclusively in the manufacture of coal gas.

*Anthracite* is a particularly hard clean sootless coal, not useful for open fires, but especially valuable for closed furnaces or stoves with an adjustable draught. It contains very little gas and is more mineral than other coals, seemingly having been formed from bituminous coal by pressure. Under appropriate conditions it has a very high calorific value. Since it approaches pure carbon in composition it has great reducing power and it is used in the preparation of producer and water gas.

Anthracite is not nearly so widely distributed as bituminous coals, the chief centres being the western portion of the S. Wales coalfield and in Pennsylvania.

The world's consumption of coal exceeds 1,100,000,000 tons yearly. This is supplied chiefly by the United States, whose yield is now 500,000,000 tons, the United Kingdom—capable, without

mechanical improvements but with settled labour conditions, of an annual output of 280,000,000 tons—and Germany. Germany will not in the near future produce so much coal as formerly, since the Dombrovo coalfield is now outside her borders, whilst the produce of the rich Saar and Moselle fields now goes to France in accordance with the terms of the Peace Treaty.

Other fairly important coal producing countries in the immediate future will be Poland, Austria, India, Siberia, and Japan.

As regards the known coal resources yet unexhausted those of China and Canada are most important. The Campine field in Belgium, the Dover and Boulonnais fields in England and France are known to have important reserves of coal, the Dover field alone being estimated to contain 10,000,000,000 tons of coal and capable of an output of 40,000,000 tons per annum. Of the remaining British coalfields the Yorkshire area contains the greatest amount of coal yet to come, particularly on its eastern flank.

The total estimated workable coal reserves of the world exceed six and a half billion tons.

The future of coal and coal mining is not easy to see. High prices, especially of transport and labour, may drive the industry to other regions, or they may lead to improved and cheaper methods of dealing with the coal. Mechanical extraction may take place, or the coal may be converted into gas or electrical energy on the field or even, perhaps, in situ. At present the outstanding fact in the situation is that U.S.A. coal can be delivered cheaper in Western Europe than can British coal. This will be of great significance to such countries as Italy, France, and Spain, which have hitherto bought large quantities of British coal, although since the opening of the St. Gothard Tunnel Italy has procured large supplies from Germany. All of this, too, has to be viewed in the important light of the return cargo. Before the war the eastern United States were already importing Spanish and Algerian iron ore; if she exports coal to these countries then increasing quantities of ore will be sent to her, and if Britain has no cargo to offer in return Spanish iron ores will have to pay higher freights to England.

Water power and oil supplies have an important bearing on the future of coal.

**BRIQUETTES.**—Low grade and small coal is sometimes rendered more convenient and serviceable by compression into blocks with a suitable binding material, *e.g.* asphalt, tar, clay, starch, etc.

The U.S.A. geological survey found, after exhaustive tests on locomotives, that briquette coal caused more smoke than ordinary coal, but that the loss of heat due to smoke was no greater. Briquettes had a greater heat value than natural coal but not sufficiently greater to balance the cost of manufacture of the briquettes. Briquettes are almost universally used in firing locomotives on the Continent, generally with about three times their weight of natural coal.

**WATER.**—In countries with a high rainfall and mountains water is an extremely important source of power. It can be used directly to drive water-wheels, but it is increasingly used to drive turbines which drive dynamos. Countries like Canada, Italy (N.), Scotland, Norway, Switzerland, may in the future become great manufacturing states due to this source of power. Some of the great falls of the world are enormous reservoirs of power, the Niagara Falls alone being estimated to be capable of furnishing 5,000,000 horse-power, and some of this is already delivered to Syracuse, 150 miles distant.

**THE COAL GAS INDUSTRY.**—When coal is distilled steam and gases are evolved which condense to water, tar, and gases, whilst coke remains in the retort. The retorts are made of fireclay, and a battery of them is heated in a single furnace. The fuel nowadays is nearly always gas and a limited air supply is fed in, part to the bottom and part to the top of the furnace. The retorts are filled with bituminous or cannel coal and a furnace temperature of over 1,100° C. is attained. The gases liberated from the coal pass under their own pressure through a water seal, and in this trap some of the less volatile constituents are collected.

It should be noted that the higher the temperature of production the greater the yield of gas but the lower the illuminating power. But since gas is now hardly used for its intrinsic illuminating properties the modern tendency is towards a very high temperature of distillation.

At 1,200° C. distillation temperature, about 12,000 cubic ft. of

gas are obtained from a ton of good coal, though generally the yield is in the neighbourhood of 10,000 cubic ft. (17 per cent). At the same time about 10 gallons of tar, (115 lb. or 5.1 per cent), and 177 lb. (7.9 per cent) of ammoniacal liquor (without added water) and about 1,570 lb. of coke (70 per cent) are produced.

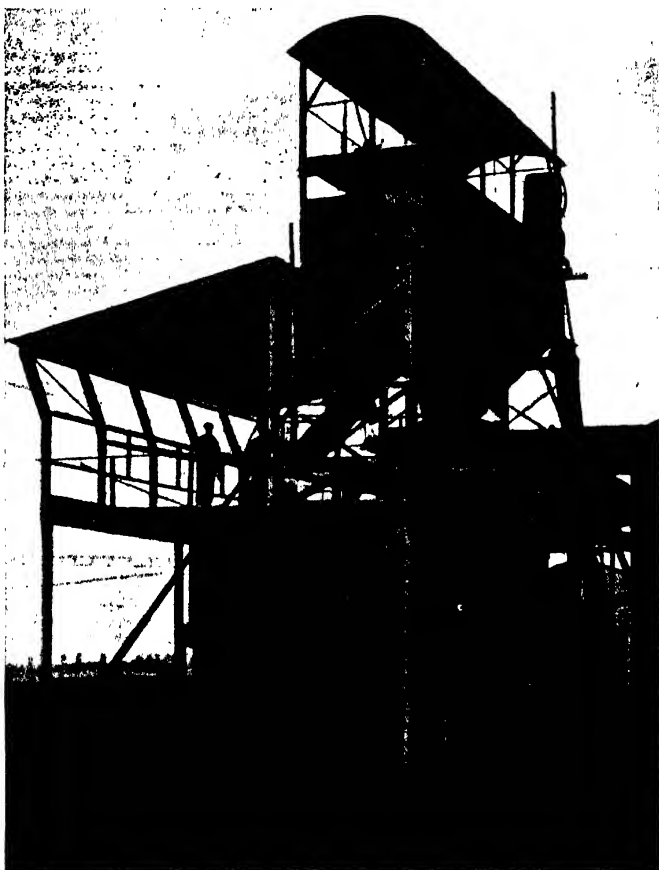
After passing through the hydraulic main (water seal) the gas is conducted through condensers. These are usually an air-cooled series of pipes and in them the tar and much ammonia-containing liquid are condensed. There is a controlled outlet from this into a tar well, into which tar can be drawn. In the tar well there accumulates two layers of liquid, the lower one being tar and the upper consisting principally of a solution of ammonia and ammonium compounds (gas liquor). The residual gas is drawn through the condensers by an exhaust fan or pump at a convenient rate. From the condensers the gas now passes to the scrubbers, an apparatus which replaces the drying bottle of the laboratory experiment. The scrubber consists of a tower containing some means of offering a large water surface to the ascending gas, *e.g.* a coke packing over which water or ammonia liquor trickles. The first scrubber often contains dilute ammoniacal liquor, since this being alkaline most efficiently removes acid gases such as hydrogen sulphide, and carbon dioxide. The second scrubber will contain pure water, which takes out all the ammonia, whilst a third one, containing sodium hydroxide solution and ferrous sulphate (green vitriol), ensures that any cyanogen is converted into sodium ferrocyanide (the source of the cyanide used on a vast scale in gold extraction and in Prussian blue). The next stage is that of purification, since the gas still contains sulphuretted hydrogen, carbon dioxide, and carbon disulphide and water vapour.

The purifiers are large boxes containing many shelves, on which the purifying material is spread. This is usually slaked lime, which forms calcium carbonate with the carbon dioxide, and also removes some sulphuretted hydrogen, forming calcium hydrosulphide, which in turn absorbs some carbon disulphide with the production of a basic calcium thio-carbonate with liberation of sulphuretted hydrogen.

Another purifier usually contains bog iron ore or Weldon mud completely to remove the sulphuretted hydrogen. When bog iron



ore is "spent" it can be reoxidized by the atmosphere with formation of sulphur, and thus can be used many times. Even then it is not done with, for it passes on to the sulphuric acid factory to be



THE KERPELY FUEL GAS PRODUCER

converted into sulphuric acid. The carbon disulphide is rarely entirely removed.

The now pure gas is stored in a gas holder, usually a great telescopic inverted iron basin working in a water tank and balanced by weights over pulleys on a frame. It is, to all intents and

purposes, a great telescopic gas jar. The gas from the gasometer, after passing through a "governor" which regulates its service pressure, is fed through a pipe line to the consumer.

Pure coal gas would give analyses something like the following—

	A.	B.
Hydrogen	47.9%	49
Methane	33.3%	35
Paraffins	7.9%	2.5
Olefines	3.5%	4.0
Benzenes	.9%	.5
Oxygen	.5%	.5
Carbon monoxide	6.0%	4
Nitrogen	—	4.0
Carbon dioxide	—	.5

During and since the war the gas is of somewhat different composition; it seems to contain more sulphides and naphthalene and probably less benzene, etc.

Coal gas is used for lighting to some extent, and for heating. It should be recognized that in the "incandescent" light the gas is used as a heating and not as a lighting medium. The gas burns with an almost colourless but hot flame, and then heats the salts in the mantle until they glow. It is these incandescent salts that are the illuminant. In view of this it is time that a heat standard, and not a light standard, was fixed for gas.\*

Gas can make an explosive mixture with air, and this is taken advantage of in the gas engine.

Coal gas is lighter than air and can be used for filling balloons and airships.

**By-Products of the Gas Industry.**—The substance left in the retorts is coke, a substance nearly all carbon but containing some sulphur. It is used, amongst other ways, in helping to heat the retorts in some gas factories, and as a general fuel for closed ranges and furnaces, being very similar to anthracite. Very high temperatures can be obtained by coke fires.

Coke is a smokeless fuel and therefore in great demand for factories in towns. It is used in the preparation of producer gas and also when a large surface is required for washing or drying gases, *e.g.* in the scrubbers of gas works.

Coke is very light, and it is therefore used in ferro-concrete

\* Since writing the above a heat standard for gas has been made law by Parliament, although, except in one instance, it is not yet in use.

buildings and cantilever galleries as a packing. Such coke breeze should be free from sulphur.

**The Gas Liquor.**—The gas liquor consists chiefly of a strong solution of ammonia and ammonium salts. The salts can be crystallized out and the ammoniacal liquid is boiled with slaked lime and the ammonia set free sold, either as a solution of the gas, or it can be neutralized by sulphuric acid and crystallized, when ammonium sulphate a valuable fertilizer, results ; or else with hydrochloric acid when ammonium chloride (sal ammoniac) crystals are obtained. The liquid from the scrubbers also contains ammonia.

**The Tar Liquor.**—Gas tar is one of the most important of modern commodities and huge industries are based upon its derived products.

The tar is distilled in large iron retorts and the products condensed in water-cooled iron worms. The distillate is collected in different fractions.

The process of fractional distillation depends upon two chief facts : (1) that all substances give off vapour, and that when the pressure of this vapour is equal to that of the atmosphere the substance will boil, and (2) that all liquids while they are being converted into vapour require a large amount of heat (latent heat), and so, since all the heat furnished is consumed in turning the liquid into vapour, the temperature of a boiling liquid does not rise. As a consequence of these and some other considerations many mixtures of liquids can be separated by distillation. For as soon as the vapour pressure of one of them reaches atmospheric pressure that one will boil, and, since while it is boiling the temperature will not rise, no other of the liquids present will boil at the same time, provided they have different boiling points. Thus fairly pure vapour of the liquid which is boiling can be obtained, and by its condensation the liquid itself is produced. Repetitions of the above process usually result in obtaining the liquid constituents practically pure. Modern fractionating stills are very ingenious pieces of engineering apparatus, and as many as 100 distillations can be carried on simultaneously by utilizing the heat of the most recently produced vapour in order to redistil condensed liquid.

When an average specimen of coal tar is distilled the first

fractionation is carried out between well-marked limits of temperature.

The distillate, which is less dense than water, comes over up to  $150^{\circ}\text{C.}$  or  $170^{\circ}\text{C.}$ , and is called light oil.

That portion of the distillate, which has about the same density as water, is called middle oil ; it comes over from  $150^{\circ}\text{C.}$ – $210^{\circ}\text{C.}$  or  $170^{\circ}\text{C.}$ – $230^{\circ}\text{C.}$  The distillate, which is heavier than water, is divided into heavy oil, which distils from  $210^{\circ}\text{C.}$  or  $230^{\circ}\text{C.}$  up to  $270^{\circ}\text{C.}$ , and anthracene oil, which comes over from  $270^{\circ}\text{C.}$ – $400^{\circ}\text{C.}$

**Light Oil.**—The light oil is redistilled and fractions collected up to  $110^{\circ}\text{C.}$  which contains 90 per cent of benzenes, from  $110^{\circ}\text{C.}$ – $140^{\circ}\text{C.}$ , which contains 50 per cent benzenes, and from  $110^{\circ}\text{C.}$  up to  $150^{\circ}\text{C.}$ – $170^{\circ}\text{C.}$ , which contains principally solvent naphtha. All of these fractions, and especially the last, will hold some aniline and other bases and some phenol and other oxybenzenes. The aniline, etc., being basic, make salts with acid. These salts are soluble in water and so by treating the fractions with sulphuric acid and washing with water these bodies can be removed.

Phenol is an acid and makes, with caustic soda, a soluble sodium salt. Therefore, after removal of the bases the fractions are separately washed, first with caustic soda, and then with water. Drying and redistillation of these purified fractions results in the collection of practically pure benzene (boiling at  $80.4^{\circ}\text{C.}$ ), toluene, etc., whilst the washings can be worked up for aniline, etc., and phenol (carbolic acid).

Any products of the redistillation of these fractions which do not pass over at  $150^{\circ}\text{C.}$ – $170^{\circ}\text{C.}$  are added to the middle oil.

**Middle Oil.**—Meanwhile the middle oil has, on cooling and standing, separated into a solid portion (naphthalene) and a liquid portion. The solid portion is removed, filter pressed, and washed to remove phenol, etc., and distilled with steam, and then that distillate is sublimed.

Naphthalene is a white characteristic smelling crystalline solid melting at  $79^{\circ}\text{C.}$  It is sometimes used under the name of carbon as a preventive against moths and as a disinfectant. It is the mother substance of a very large number of dyes, and in particular it is the parent substance of phthalic anhydride, which is the starting point in the manufacture of synthetic indigo.

The liquid portion of middle oil is washed with caustic soda solution. This converts all phenol, cresol, xylol, etc., into soluble sodium salts. The solution of these is removed and the remaining portion, insoluble in water, added to a fresh portion of middle oil and allowed to stand, etc. The solution of sodium salts is acidified, by which means phenol, cresols, etc., are regenerated and the oil layer of them separated, dried and fractionally distilled. Pure phenol, the three cresols, and the xylols are obtained from this fraction. All of these substances are strongly antiseptic, aromatic, crystalline solids, which are slightly soluble in water and in which water dissolves to form a liquid.

They are, all of them, used as disinfectants and antiseptic washes. Phenol, or carbolic acid, is domestically used for this purpose, whilst the others are used in the hospitals, etc. An emulsion of the xylols with soap, which dissolves in water in all proportions, is sold under the name of Lysol. These substances are also used in the preparation of a large number of organic substances, *e.g.* tri-nitro phenol (picric acid, a constituent of lyddite and other explosives) and of a very large number of dyes.

**Heavy Oil.**—The heavy oil is used without further manufacture for preserving timber, *e.g.* railway sleepers. These are put into iron cases and the sap forced out at the same time as the creosote enters under pressure. The anthracene oil furnishes anthracene, which is a constituent of many dyes.

After the tar has first been distilled the non-volatile matter left in the retort is drawn off. On cooling it solidifies to pitch, which is chiefly used for "tarring" roads and in making artificial asphalt.

Pitch is found naturally in Trinidad, where there is a lake of it, Val de Travers, and California. This has probably been prepared very similarly to the artificial variety. It is better than the artificial pitch for road-making.

The most important of all the products of coal tar is benzene; only about 1.1 lb. of this substance is obtained from an average ton of coal + about .9 lb. of toluene, which is almost as useful.

Benzene is used as a motor spirit and for cleaning. It is used directly or indirectly in the manufacture of nitrobenzene and aniline, of saccharine, of many dyes, of a large number of synthetic drugs, and many perfumes and flavourings. Toluene has many of

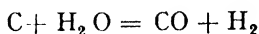
the foregoing uses, though its higher boiling point prevents its use as a motor propellant. Its trinitrate is T.N.T., a much used explosive.

In an economical engine coal gas would, at 5s. per 1,000 cubic ft., be about equivalent to coal at 50s. per ton. Since these are not far from the actual prices in London at the present time, it can be seen that there is not very much advantage in a coal-gas engine except that it is started much more easily than a coal-steam engine. This has led to a good deal of research in trying to obtain gas suitable for gas engines at a lower relative rate.

The first attempts were in the direction of burning coke with only a limited quantity of air (as in the primary heating of a gas retort) whereby the carbon of the coke is burned to carbon monoxide only (CO). Siemens gas was made by having a large quantity of coke in an upright cylinder and forcing in only enough air at the bottom to burn the coke at the bottom. This fire at the bottom heated the coke above it to such a temperature that it reduced the carbon dioxide, which was the product of combustion of the coke burning below, to carbon monoxide. The gas so produced, however, was not used for explosion purposes but for actual burning as a fuel in the manufacture of steel and glass.

Since the calorific value of the producer gas (as the carbon monoxide is called) is only about 70 per cent of that of the coke from which it is produced, where heat alone is the consideration this is not an economical process.

**Water Gas.**—If steam instead of air be forced on to the coke under circumstances like the preceding, and at an appropriate temperature (650–900° C.) the coke burns in the steam, producing, ideally, carbon monoxide and hydrogen—



This mixture has a very high calorific value, so high, indeed, that no engine has yet been devised that can stand its explosion. (Cylinders melt or buckle, etc.) Further, the passing of steam over coke results in a fall in temperature and outside heat is required.

Dowson gas is a mixture of water gas and producer gas. In its manufacture either a mixture of steam and air is blown over the

hot coke, or, better, first steam is blown over the coke until the temperature falls below an economic level, and then the steam blast is cut off and air blown over. This, besides producing carbon monoxide, also effects a rapid rise in the temperature of the coke, and as soon as the required temperature is reached the air is cut off and the steam turned on again, and so on. This mixture is very cheap to produce (probably even to-day it would not cost more than 4d. per 1,000 cubic ft.), and it is, moreover, admirably suited for use in the gas engine.

A further modification has been the passing of the air and steam over the fuel by means of suction, which is provided by the forward stroke of the piston of the engine. In this case bituminous coal and peat can be used although since the tarry matter generated would give rise to products which would carbonize in the cylinders of the engine, various plants have been constructed to avoid this. In them peat, lignite, and inferior bituminous coal can all be used as in the case of the Mond gas producer. In this process the tar and the ammonia are removed by a water spray and scrubbers. The ammonia is converted into ammonium sulphate, which is marketed.

Water gas is sometimes converted into illuminating gas by spraying into it oil, naphthalene, etc., and submitting the mixture to such a high temperature as will crack the oil, converting it into hydrocarbons, which are permanent gases and which burn with a luminous flame. This mixture is called enriched water gas. If water gas is to be used to heat gas mantles all the iron carbonyl must be removed.

Water gas, producer gas, and Mond gas have no smell, and since, from the large quantity of carbon monoxide they contain, they are highly poisonous, in addition, of course, to being explosive, a small quantity of phenyl carbylamine, "a substance with an intolerable smell," is sometimes introduced so that a leak can be detected. This is called "perfuming." Of course the blast in an ordinary blast furnace is really a kind of water gas.

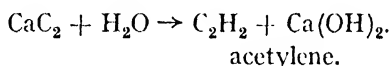
**Natural Gas.**—When borings are made for oil the first product which is obtained is sometimes a gas, natural gas, of very high calorific power, and where it occurs it is a valuable fuel. It is, however, too sparsely distributed to be in general use.

**Petrol and Benzene Motors.**—These contain contrivances, the carburettor, for converting a portable liquid into gaseous fuel, and after that they are gas engines.

Before leaving gaseous fuels it should be borne in mind that they have advantages over and above their calorific value. They are clean in use and, properly burned, produce no sedimentary ash but yield the final oxidation products of water and carbon dioxide. They require no laborious stoking and can be delivered where required.

**ACETYLENE.**—Acetylene is an unsaturated hydrocarbon and therefore burns with a luminous flame. Since it is highly unsaturated its flame is very bright and it is used as an illuminant.

It is prepared very simply by a drip of water on to calcium carbide, whereby acetylene and slaked lime are formed—



Acetylene burns in oxygen with a very hot flame, so hot as to raise steel to its ignition point. Therefore steel which is heated by the oxy-acetylene flame will burn in air. In practice a jet of the oxy-acetylene flame is played on to a piece of steel. The steel in the neighbourhood of the flame burns away and by moving the jet a "cut" can be made in the steel similar to that made by a saw in wood. This is especially useful for removing damaged pieces of plating, etc., and leaving only sound material behind.

Acetylene is also used to melt steel in situ, and so cause the molten edges of two pieces of steel to flow together, as it were, using steel as a solder to solder itself. This is called acetylene welding.

Acetylene is at ordinary temperatures a rather unstable gas, and when compressed an explosively unstable gas if in metal cylinders. Great care has therefore to be exercised in the storage and transport of acetylene. In this connection it is fortunate that it is so easily generated.

**PETROLEUM.**—Petroleum is a liquid found in a crude state in the earth. Much work has been done upon the question of its origin, but since it is usually found under conditions where the natural distillation products of vegetation could be prevented



from escape by an inverted basin of impermeable rock it is generally concluded that it has been formed by the natural destructive distillation of peat, etc., and probably also of the animal remains contained therein. More than two-thirds of the world's supply comes from the United States, especially Pennsylvania and Texas, and in that country it is found in the Devonian and carboniferous rocks. The remaining chief source (with full production) would be Russia (Baku on the Caspian). In Russia and the other European sources (Galicia, Rumania) petroleum is located in the tertiary system. Other supplies come from Persia and Mesopotamia (this bids fair to be important), India, Burma, Nigeria, Dutch E. Indies, Mexico, Colombia, and at the present time borings are being conducted in England, near Chesterfield, and a company with £1,500,000 capital has been formed. This sounds rather ambitious.

American and most other petroleums consist of a mixture of paraffins (hydrocarbons of the series  $C_nH_{2n+2}$ ), but Russian petroleum contains, mostly, naphthenes (hexahydro benzenes).

In the extraction of petroleum from the earth borings are made and the hole lined with a steel tube. When the oil-bearing strata are reached the pressure of imprisoned gas may force the petroleum to the surface as a "gusher" and vast quantities of oil and accompanying gas have been lost in this way. To minimize waste, "divers" in appropriate dress are sent to seal and tap the outlet of the boring. Generally speaking, the oil has to be pumped to the surface, or it may be baled out by a huge baler about 60 ft. long (this is used when the petroleum is much mixed with sand), or an absorbent endless band may circulate through the boring, becoming saturated with the oil which is expressed when the band passes between rollers above ground. A further method sometimes practised is so to decrease its density by blowing air into it so that it will flow out of its own accord. The petroleum, when it reaches the surface, is passed into a reservoir to await purification.

Crude petroleum is a strong-smelling, brown, fluorescent, oily liquid, which is a mixture, or a compound, of very many liquids (thirty or more).

Petroleum is purified by fractional distillation. The lower



THE GLEN POOL  
●  
One of America's oil-producing centres

boiling fractions, including petrol, benzoline, gasoline, and ligroin (petroleum ether), all boil below  $130^{\circ}\text{C}.$ ; they are butane (which is sometimes used in refrigerating machines instead of ammonia), pentane (boiling below  $18^{\circ}\text{C}.$ ), and more pentanes, hexanes, and heptane. Gasoline boils at about  $46^{\circ}\text{C}.$  and petrol at  $60^{\circ}\text{C}.$  The fraction which comes over from  $130^{\circ}\text{C}.$ – $275^{\circ}\text{C}.$  is kerosene or ordinary domestic paraffin. Above  $275^{\circ}\text{C}.$  or  $300^{\circ}\text{C}.$  the product is lubricating oil. Each fraction is purified by washing with sulphuric acid; the acid is removed by caustic soda and the fraction further purified by redistillation.

Various specific by-products include vaseline (M.P. 30–40) or its equivalents (for vaseline is a patent name) and paraffin wax.

Russian petroleum is much less volatile than American petroleum. It contains about 10 per cent of benzene, and its homologues, and the remainder consists of naphthenes.

Petroleum is in America usually refined at the coast. Both in Russia and in America it is transported by being pumped along pipes which lead to the port of shipment. Some of these pipe lines are of very great length, that from Baku to Batoum being 500 miles. The process of barrelling was too expensive and oil is shipped in "tankers," *i.e.* about 6,000–8,000 ton steamers, which are just large tanks with the necessary means of propulsion and housing for the crew. The steamers are filled direct from the pipe line.

**Uses of Petroleum and Petroleum Products.**—Crude petroleum is used as a fuel for steam-engines and on ships, etc. The lowest refined fractions are used as refrigerators, and the portions boiling from 30 upwards are used in explosion engines for motor cars, aeroplanes, and submarines. The middle fraction is a very valuable illuminant. The higher fractions are the most frequently used and most valuable lubricants. Vaseline and paraffin are used as salves, and paraffin forms a most excellent insulator. Paraffin oil is poured over pools and other stagnant water to prevent the emergence of those mosquitoes which distribute malaria and yellow fever. Solid petroleum residues form valuable fuel, especially on the Volga, etc.

Shales are deposits of clay without the typical cleavage planes

of slate. At Broxburn in Scotland, and in Saxony black shales are mined which, on distillation, yield gas and typical petroleum products.

Alcohol is also used as a liquid fuel, particularly in the form of methylated spirit, as well as some vegetable oils. Colza oil (rapeseed oil) is a well-known illuminant.

## CHAPTER XI

### POTTERY AND GLASSWARE.

POTTERY-MAKING is the very earliest of the arts practised by mankind, and specimens of pottery have been found in the "barrows" in England, the caves of Central France, and the lake dwellings of Switzerland. The earliest pottery was probably sun-dried clay, after which the introduction of artificial heat is easily understandable.

**CLAY.**—The chief raw material for all kinds of pottery is clay, and for fair and good quality "china" this clay must be white "Cornish" clay or kaolin (hydrated aluminium silicate) found in Cornwall, Saxony, Limoges, and U.S.A. This is purified at the quarries, *e.g.* St. Austell, by breaking up, mixing with water to a paste and allowing the paste to flow through grooves called "drags," where the harder and heavier matter settles. The paste then flows into settling tanks, where the pure china clay is deposited. Other important pottery materials include Dorsetshire blue clay, Cornish stone, which fluxes the ware into a compact texture, silica and felspar. The silica ( $\text{SiO}_2$ ) is made by burning and grinding flints, whilst the felspar, which is much used in the glazes, and also forms an important ingredient in statuary porcelain, is quarried in Sweden.

The ingredients, the quantities of which vary in different works, are made into a fairly thin paste (slip) with water, and the slip is carefully dried until a workable paste results. This paste is then made into shape on the potter's wheel by hand (the craftsman is called a thrower), it may be pressed into plaster moulds, or indeed, the slip, while still able to pour, may be poured into moulds. Insides of cups, etc., are usually turned out on a lathe.

The shaped clay is allowed to dry, and then each article is placed in a receptacle called a saggar.

**Saggar** is a kind of fire-clay from which ovens capable of resisting high temperature can be made. It is found in the "Potteries," and that is one of the reasons why the pottery industry is located in N. Staffordshire. The saggars are built up in piles (as many as

48 piles, or bungs as they are called) in ovens or kilns. The kiln is bricked up and the fire started through purposely-left fireholes. The firing is at first at a low temperature, being gradually increased as the moisture is driven off. The temperature of the heating is very important, as it determines to a large extent the character of the product, and various devices have been adopted to have it recorded and so controlled. One of the best and most ingenious is to make tetrahedra (cones) of mixtures of different known melting points and heat them in the kiln with the saggars. As the cones successively fuse the temperatures are known. Porcelain may be heated to as high a temperature as  $1,410^{\circ}\text{C.} = \text{cone } 10$ .

The firing takes from forty hours to three days in normal cases, although for important work it may take very much longer. When the pottery is judged sufficiently heated the kiln is allowed to cool very slowly. Usually nearly as long a time is allowed for cooling as for heating. For certain classes of goods this treatment is sufficient, and if such work is required to be glazed this is done by the introduction of salt when the furnace is at its hottest. The effect of this is to provide an insoluble silicate, which is a glass, on the surface of the articles. Ordinary glazed stoneware and tiles are thus manufactured, but generally the "biscuit" ware produced by the first treatment is decorated by stencilling, printing, transferring, or hand-painting, and after the colours are set it is dipped into the glazing medium. This may consist of very finely ground borax, felspar, whiting, etc., fused together, mixed with china clay, silica and white or red lead, and the whole made into a paste with water. The pottery operatives usually receive the red or white lead worked up into a silicate, since they are then harmless, or leadless glazes are now used. The dipped goods put back in saggars are then heated in a "ghost" oven until they are coated in a glass, and after cooling are ready for the market unless further decoration is required. If so, after the colour has been applied, they must be again heated.

Pottery can be divided into the three main groups: earthenware, fired at a low temperature; stoneware, which is heated to a higher temperature and which is as a rule of an inferior character, and porcelain, which is almost a glass, is semi-transparent, and which is heated to a very high temperature.

Silicon china is a sort of semi-earthenware with some properties of porcelain.

**Porcelain.**—The manufacture of porcelain was introduced to Meissen, near Dresden, from China, which gave the substance its name. Some time after, Josiah Wedgwood introduced the industry into England, and now the finer English manufactures are bettered by none in the world.

Some of the more famous English porcelains are Worcester, Crown Derby, Coalport, and the chief manufacturing towns include Worcester, Burslem, and Stoke, and the whole pottery district.

Valuable foreign porcelains are made at Meissen (Dresden china), Sèvres (Paris), Limoges, China and Japan. Berlin china is unique in its heat-resisting qualities and is used, when procurable, by chemists and other scientists all over the world.

**GLASS.**—Glass is a supercooled solution of various silicates in the solid state. It is not a stable article and must eventually crystallize. The simplest of all glasses is made by fusing together soda ash (sodium carbonate) and silica (clean sand). The substance which results is sodium silicate, a clear transparent solid which, however, is soluble in water and is therefore not suitable for the ordinary purposes for which glass is used. This soluble water glass is, however, used in the preservation of stone. Limestones are apt to crumble on prolonged exposure in towns. If, however, the surface be painted with a solution of sodium silicate it is eventually converted into a sort of glass or sodium calcium silicate which is practically unacted upon by the weather. Solutions of sodium silicate are also much used as preservatives for eggs in the shells. The action on the shell is the same as that on limestone and the shell is rendered impervious to the air, etc.

In order to convert soluble water glass into a true glass some ingredient is necessary which will secure the formation of an insoluble silicate. This is usually lime, added in the form of limestone, for ordinary use when a sodium calcium silicate is produced, called crown glass, or red lead is added if a glass for cutting is required. In this latter case potassium carbonate may be used instead of sodium carbonate, and the potassium lead silicate produced is called flint glass. Many other ingredients are used, *e.g.* manganese dioxide, usually with the purpose of securing

colourlessness and transparency. The mixture is heated in crucibles in a circular furnace, although very cheap glass may be made in fireclay tanks heated by producer gas. The sands used come from Fontainebleau, Lippe (Germany), Belgium, and Lynn and Leighton (Beds), in England. Sodium sulphate (salt-cake), *q.v.*, may be used instead of soda ash.

In working the inferior kinds of glass some is withdrawn from the tank described above on an iron rod, something like treacle on a spoon, and then this is allowed to flow into the mould. The inside is hollowed out by a machine-driven plunger and the whole blown to fit the mould by compressed air. In good glass work the glass is withdrawn from the pot on a polished iron tube. The semi-molten mass is mouth-blown into shape and superfluous parts cut away by shears.

Plate and sheet glass are made by pouring the molten glass on to an iron or gannister table and pressing by a following roller. Plate glass is afterwards polished by friction.

Glasses for special purposes are made by varying the constituents. Soda glasses are, as a rule, not resistant to heat and are also sufficiently soluble in water for them to be objectionable in certain chemical processes, and to meet this difficulty Schott's of Jena have produced potash resistance glasses, which are very good indeed. Optical glasses having every required refractive index are also produced by this firm.

However glass is manufactured, and for whatever purpose, it must be annealed, otherwise it would be liable to crack. Annealing consists in heating at a fairly low temperature for some time and then cooling very slowly indeed.

Although cheap glass is moulded the better varieties are cut. This may be done either with a copper wheel and emery powder, or by means of a drip of wet sand which falls on to the edge of a wheel. Grinding is also done by sand and water and polishing by rouge or some similar material.

The colouring of glasses is effected by adding various metallic oxides as well as the metals themselves. Gold is one of the most important metals used, and the colour is produced by ultra-microscopic particles of the element itself. When added at a certain temperature metallic gold produces the clearest crystal



glass. Copper oxide, iron, antimony, cobalt, etc., and platinum are also used.

The great centres of the glass industry are on the S. Belgian coalfield for plate glass (the Belgian sand is very suitable); Austria, Germany, France, U.S.A., with its natural gas, for ordinary glass work; Bohemia and Jena for chemical and optical glasses; and Murano and London produce the finest table and coloured glasses. The centres of the British general glass industry are Newcastle and St. Helens.

Silica glass is silica ( $\text{SiO}_2$ ) which has been fused until it becomes, when set, a transparent or semi-transparent mass. It is used for suspension fibres for electrical and physical instruments and, because of its very low coefficient of expansion, and high melting point, as a material for apparatus which has to be heated to high temperatures. A silica tube heated in a furnace to above  $1,000^\circ \text{C}$ . can have its projecting ends kept cool with cold water without cracking.

**ENAMELS.**—Enamels are special glasses for applying to the surfaces of metals. The base is an ordinary glass coloured with various metallic oxides or metals, *e.g.* gold, copper, iron, manganese, etc. This produces a transparent enamel; if an opaque enamel is desired oxide of tin is added. The ingredients are generally ground up together and then melted and poured into water.

When this enamel is to be applied it is made into a paste with water, painted on to the metal and heated until it just flows. Sometimes gold wires are used to make the design (*cloisonné* work).

Iron for domestic articles and advertisement plates, etc., is enamelled by painting with soluble water glass (sodium silicate solution) and then putting on the powdered enamel and firing until the enamel flows to a homogeneous mass.

Enamel paints are paints containing varnish, and are not true enamels.

## CHAPTER XII

### BUILDING MATERIALS AND ALLIED PRODUCTS

**BUILDING MATERIALS OF INORGANIC ORIGIN.**—Nothing shows more completely the effect of place on man than his selection of building materials in different localities. They vary from the ice and snow-roofed igloos of the Eskimo in winter, through the leaf and wattle-walled huts of typical savages, and the adobe houses of the Mexicans, to the steel and concrete sky-scraper of New York.

**Stone.**—Stone is one of the most important of building materials and it has been used from time immemorial. The cave dwellings, which were amongst the earliest of all human habitations, were made of stone although not by human hands. Neolithic man, however, decorated them. Stone was used to build the pyramids by the ancient Egyptians, and ever since then men have used stone as a material, at least for their more important buildings. Stone is more durable than any other of the building substances. Stone can be a solidification of a fused mass, in which case it is very often crystalline and is said to be of plutonic origin, or it can have been deposited either out of solution or as the remains of living things. Such stones are called sedimentary.

**Granite.**—The most important plutonic building stone is granite. Commercially most fire-formed rocks are called granite, although strictly speaking true granite should be similar to the product of the Rubislaw quarries of Aberdeen. It is an entirely crystalline rock of a non-homogeneous character. It must contain intermingled crystals of quartz ( $\text{SiO}_2$ ), orthoclase (potash felspar, potassium aluminium silicate), potash mica (talc or muscovite), and biotite (black mica.) Other so-called granites contain hornblende and augite. The pyramids were built of eyenite. When the orthoclase, which is a constituent of all granites, contains much iron red granites result (Peterhead). Cornwall, Leicestershire, Cumberland, Aberdeen, Peterhead, Newry, Massachusetts, Maine, and Vermont produce much granite, as well as Sweden, Norway, Germany, France and Canada.

Granite is quarried by blasting. It is too hard to be worked by hand, but is worked by sawing with tiny particles of iron and water on an iron band. It is chipped with pneumatic tools. Cylindrical and circular work is rough cast by lathes. Granite is polished by rubbing with powdered hard stone.

**Sandstone.**—Sandstone is a sedimentary rock consisting mainly of grains of silica cemented together. If the cementing material is itself silicious quite hard rock may result.

Sandstone may be laid down in beds of quite extraordinary thickness, the Torridon sandstone, which covered parts of Scotland, having been 10,000 ft. thick.

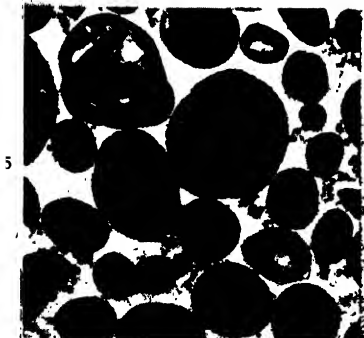
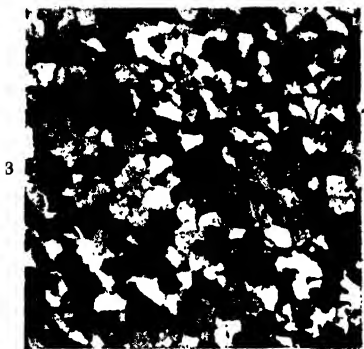
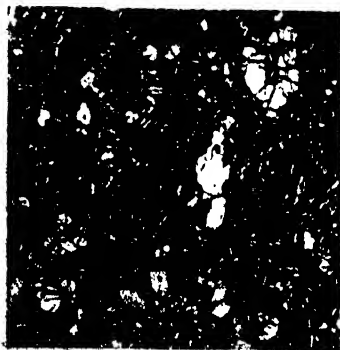
Of the British sandstones those most used for building purposes include the Craigleith stone quarried near Edinburgh, the Pennant grit of S. Wales, and the old Red Sandstone of Herefordshire.

Sandstones, because of their texture, are admirably adapted for grinding purposes, and nearly all millstones, oilstones, etc., are forms of sandstone. These gritstones are usually found in the coal measures, *e.g.* Derbyshire and Yorkshire.

The millstone grit is much used for road metal on hills where limestone would be unsuitable because of its smoothness, since the grit, as its name implies, affords a rough foothold. Gannister, used for furnace linings, etc., is a form of sandstone.

The building stones in most general use are the various forms of calcium carbonate. These have mostly been laid down under the sea from the skeletons of the microscopic foraminifera, although in the case of marbles they have subsequently been changed by heat to igneous rocks (rocks which have been changed in this way are called metamorphic rocks).

**The Oolitic Limestones.**—These have the appearance (under the microscope) of little rounded grains (fish roe). The most important deposits in England are at Box and Portland. The Romans built the baths at Bath of Bath stone which probably came from Box. Bath stone is mined at depths of about 100 ft. The stone is removed by holing, not like coal, however, below the rock to be removed, but above it. The rock is then sawn and wedged out. removed on horse-tramways to the shaft where it is elevated to the surface. It is interesting to remember that the originator of the revival in the Bath stone industry was the Squire Allworthy in



# TYPICAL STRUCTURES IN STONE

- |                    |                      |                     |
|--------------------|----------------------|---------------------|
| 1. Granite         | 2. Basalt            | 3. Sandstone        |
| 4. Granite-porphry | 5. Oolitic Limestone | 6. Shelly Limestone |

*Tom Jones.* His real name was Ralph Allen. Portland stone is quarried, not mined, since it comes right to the surface. It is very similar in properties to the Bath stone.

Another important carbonate rock used in building is the celebrated Red Mansfield stone. This contains magnesium carbonate as well as calcium carbonate. It was used for the building of the London Houses of Parliament.

**Marble.**—Marble, which is metamorphosed calcium carbonate, is beautifully crystalline. When pure it is white but it can be obtained in many different colours as the result of impurity.

The finest statuary and building marble comes from the world-famous quarries at Carrara (Tuscany) which produce over £500,000 worth annually. It is quarried by blasting up in the hills and after being rough-shaped it is transported down the hill sides on wooden sleds.

In Ireland marble is quarried at Connemara.

Limestone is quarried for the preparation of lime and carbon dioxide as well as for building purposes.

**Slate.**—Slate, although only used locally as a general building material, is very widely used for roofing. Slate has been formed from clays by great pressure; its chief characteristic is its perfect cleavage, whereby it can be split into thin layers.

Slates are both quarried and mined, principally in Wales, the chief quarries being at Bethesda (the Penryn quarries), Port Dinorwic, Festiniog, Portmadoc, as well as in isolated places (Corris and Bryn Eglwys).

Slates are quarried in Ireland at Killaloe and Valentia, and in Scotland (Aberfoyle, Ballachulish).

Most of the north-eastern United States produce slate, as also do Austria, France, and Canada. Slate is obtained by drilling and blasting. It is quite easily squared and planed by machinery but must be split by hand. It is of great advantage in the use of slate that holes for nails can easily be tapped in it.

In addition to being used for roofing slate is used locally for walls and fencing, and generally for billiard tables and for tanks in chemical industries.

**BRICKS.**—Bricks have been used since very early times, and one of the tasks of the Israelitish captives in ancient Egypt was the

making of bricks. These bricks were sun-dried as are the "adobes" of Mexico to-day. Bricks are made wherever there is suitable clay near the surface. In England the neighbourhoods of Peterborough, London, and Stafford are important brick-making areas. Bricks are made at Whitehill in Scotland and in most of the N.E. United States.

The clay from which bricks are made is apt to contract considerably in burning, especially if it contains an excess of alumina. Sandy clays do not shrink much, but are brittle when baked. A good brick-clay therefore contains a little sand and no excess alumina. The colour of the finished brick depends on the impurities present in the clay, especially iron, and the temperature of firing.

Bricks can be either hand or machine made. In the first case the clay, which should have been exposed to the weather all the winter, is first worked up well with water. It is then put into an open mould and the protruding clay removed. The raw (green) bricks are then stacked to dry. Some brick-making machines use the same material as for hand work, and the wet clay is forced through a die in long rectangular rods which are cut to length by wires. Other machines use clay which has been dried and powdered. In this case the mixing with water is done by means of knives in the machine itself. The wet mass is then hot-pressed into shape.

The firing of the bricks is sometimes done in brick kilns; in other cases the green bricks are built up with intervening layers of cinders into clamps with slack coal and wood for fuel at the bottom. Flues are left throughout the clamp, which is protected from the air by clay. This is fired for about three to six weeks. The kilns are much more economical of time. In the first place they are constructed in compartments so arranged that the flue gases from the firing of one lot of bricks dry the bricks in another section. This section can then be heated and the flue gases switched to another. Another advantage is that the firing only takes about two days.

Bricks are of various grades for different purposes: yellow stocks for general work, soft red rubbers for ornamental work, and the blue fire bricks of Staffordshire for blast furnaces, etc. Glazed bricks have salt thrown on them in the kiln, whilst the white

enamel bricks used in sanitary work, etc., are coated with a mixture somewhat similar to pottery glaze and reheated.

Drain pipes are made similarly to bricks, except that they are pressed through an appropriate annular mould.

**SAND.**—Sand is the product of the disintegration of rocks, and especially quartz and sandstone. Greensand, which forms the bottom of the ocean in large areas, is partly potassium iron silicate (glauconite). It outcrops in Sussex, etc., and in New Jersey. It is used for iron moulding, whilst it may contain fossil dung (coprolites) used as a phosphate manure (Cambridgeshire).

When sand consists of pure silica ( $\text{SiO}_2$ ) it is used in glass-making, and sharp sand, *i.e.* sand which is not rounded, is used in the making of mortars.

**FULLER'S EARTH** is a clay found in the greensand in Surrey, and other places. It is most worked in Somersetshire. It powders up when put into water. It is used for cleansing wool and as a cosmetic.

**PUTTY** is powdered chalk or whiting mixed with linseed oil and white lead.

## CHAPTER XIII

### PRECIOUS STONES

PRECIOUS stones are special forms of quite ordinary substances, *e.g.* the diamond is carbon. They have been sought after and highly prized throughout history almost entirely for their beauty and from the evidence of wealth that their possession affords, since they are rare and therefore costly.

**DIAMOND** is a crystalline form of carbon probably containing a different number or arrangement of atoms to the molecule from graphite, charcoal, etc.

Diamonds are found in the "pipes" of extinct volcanoes embedded in a blue rock or clay. The mines at Kimberley can produce all the world is willing to pay for at the present price, indeed, their output is artificially limited. In consequence of this diamond mining is hardly carried on in other parts of the world. Some few come from Brazil and some from India. The Kimberley diamonds were discovered by accident. In one case a pebble with which a child was playing was found to be a diamond, and in another a farmer found diamonds in the clay walls of his farmhouse. He immediately began to dig more clay from the place where the previous material had come from and found more diamonds. The mine thus commenced is still worked (Dutoit's Pan). Many other mines have been opened in the district, and since the yield of diamonds seems rather to increase with depth there can hardly be a natural limit to the output. The mines are worked from deep shafts (2,000 ft.) very similarly to coal mines, and the "blue ground," when it reaches the surface, is spread over cleared "floors" to a depth of a foot. This is with the object of its being broken up by the atmosphere, the action of which crumbles the rock. Periodically the "blue ground" is turned over so as to expose a fresh surface and it is kept constantly wet. After a year the ground is separated by milling into denser and lighter layers and the lighter part washed off. The heavier part is then allowed to drop on to a series of rocking trays (the pulsator) which are smeared with a viscous substance to which the diamonds adhere as the concentrates pass



over. The grease used is very efficient, and, letting very little escape it, retains the large stones even better than the lesser ones.

The diamonds which, when found, look very like a solid gum, are cut in Europe at Amsterdam or Antwerp, though recently an attempt has been made to establish the industry at Brighton. The stone is first carefully examined to determine which cutting will give a maximum value to the finished stone. It is then rough-shaped by splitting, after which it is "cut" by an iron wheel working in a rim of diamond dust, emery, and oil. It is then polished. The shape given is designed to furnish maximum reflection. There are two main forms, the "brilliant," a sort of flat-topped truncated cone, has fifty-eight facets, while the "rose" has twenty-four.

The value of diamonds depends on their colour and weight. The clearer the stone the greater its value, which also increases as the square of its weight. The unit of weight used was formerly a "carob" bean, which when dry had a very uniform weight. It is now called a carat, which is  $\cdot 207$  grains or about  $\frac{1}{140}$  of an ounce (av.). Diamonds when faintly tinged are of small value but full colouring is greatly prized.

Boart and carbonado are two forms of imperfect black diamond approximating to graphite which, although worthless as gems, are used in drilling and boring machines.

The diamond is the hardest substance known, and it has a very high refractive index whilst its reflecting powers are very great since it absorbs very little light. It is transparent to X-rays, which, since they will not penetrate glass serve as a means of detecting paste. Diamonds are not attacked by acids, but when ignited electrically burn to carbon dioxide leaving no ash. The rays from radium alter the colour of diamonds to advantage at times but sometimes have the effect of rendering them worthless. Many attempts have been made to make diamonds artificially. The most successful attempts were by Moissan, who heated iron to volatilization temperature with pure charcoal (from sugar) in a carbon crucible in the electric furnace. The iron dissolved the carbon and the crucible was then very suddenly quenched by plunging it into water. Under such conditions enormous pressure

was produced and the carbon was deposited in the iron in a crystalline condition. Many diamonds were formed, most of them "carbonado," but some white and transparent. They were, however, very small and would not have paid for the cost of production.

**CORUNDUM.** — After diamond and carborundum, native aluminium hydroxide (corundum) ( $\text{Al}_2\text{O}_3$ ) is the hardest substance. It is found in greenish-grey granules in Ceylon and as stratum in Massachussets (Chester), and in North Carolina. When found admixed with iron oxide it is called emery (Chester, Mass., in New York, Greece, and Asia Minor). Both corundum and emery are used as abrasives for grinding and polishing, *e.g.* sharpening and cleaning knives. Certain impure and crystalline varieties of corundum are beautiful, rare and highly valued. These impurities often impart very fine colours. The most important of these are ruby and sapphire.

Rubies are very rare and of greater value than diamonds, especially the larger stones. There is only one important mining area in the world, at Mogok, in Upper Burma, though a few come from Siam and Ceylon. The Mogok mines are worked by a British syndicate on Government lease, which expires in 1932. The mines are really open workings and the earth, after screening, is washed to remove all the lighter parts. The heavy residue is removed from the pans and screened through wire mesh of different sizes. These different screenings are further separated on a pulsator. The last operation is washing the concentrated earth by hand in a sieve after which the stones can be hand-picked. Ruby can be detected from spinel and garnet, which closely resemble it, by the dichroscope. This is quite a simple instrument which depends on the fact that two images are seen when an object is looked at through calcspar. In all dichroic substances the images are of different colours, whereas in crystals which are not dichroic the images are of the same colour. Now ruby is dichroic, whereas spinel and garnet are not, so that the calcspar crystal, which, when mounted in a tube with a lens, is called a dichroscope, reveals the difference at once. The most valuable rubies are carmine coloured (pigeon's blood). The sapphire is a blue variety of corundum and comes from Burma, Siam, and Ceylon.

Reconstructed rubies and sapphires are small stones and cuttings

which have been melted in the electric furnace and allowed to crystallize. Artificial stones have been made (Frémy) but the process does not pay commercially.

Oriental topaz is yellow corundum, Oriental emerald is corundum of a green colour, and Oriental amethyst is corundum coloured mauve.

**GARNET** is a generic name for a variety of isomorphous stone, of which carbuncle (pyrope) is one of the best known. Garnets are red or brown, but when slightly impure may be of other colours. Garnets are obtained from Saxony, Bohemia, Burma, Ceylon, and the Urals.

**EMERALD**.—Emerald is a very valuable green stone and is a slightly impure form of beryl (aluminium beryllium silicate). A blue variety of beryl is called aqua marine. The chief sources of emeralds at the present time are Siberia (Urals), Colombia, and New South Wales. Perfect emeralds are very rare and extraordinarily valuable, but when not all that is desired they may cost  $\frac{1}{10}$  of the price of the best.

**TOPAZ** is an aluminium fluosilicate. The best varieties come principally from Brazil and the Urals, although nowadays they are not in very great demand. Inferior topaz is obtained in the tin mines of Cornwall and Saxony, and also in the Mourne mountains (Ireland) and in Aberdeen.

Topaz is usually of a yellow colour and is laminated in appearance, being sometimes glassy and sometimes more opaque.

**SILICA**.—Silica (silicon oxide,  $\text{SiO}_2$ ), of which ordinary sand is one impure form and quartz another, can exist also in amorphous (non-crystalline) and semi-crystalline conditions, some of which are valued as gems.

The most sought after of these is opal, a compound of silica and water. Opal is a product of the decomposition of other rocks, notably felspar, and seems to have been deposited out of water. It is therefore often found intimately associated with other rocks, and indeed has at times so permeated wood, shells, etc., as to preserve them in fossil (petrified) condition. Most opal is of a brownish colour, and if not actually valueless is at least not precious. In certain areas, however, the typical precious opal is found (Queensland, Mexico, New South Wales, etc.). The characteristic

opalescence is most marked in the fire opals from Mexico, whilst in other varieties it may be absent. Opals are much less hard than other precious stones ( $H=6$ ) and therefore should be carefully kept if their polish is to be preserved.

**CHALCEDONY.**—Chalcedony is a generic name for forms of silica in which the amorphous variety is intimately mixed with the crystalline (crypto-crystalline forms). Like opal it is found in cavities, etc., in other rocks, in which it has been deposited from water. It occurs in a variety of colours and appearances, all of which are ornamental, and include agate, carnelian, bloodstone, chrysoprase, onyx, and jasper, as well as the one known as chalcedony.

Of the foregoing, agate, which is very hard and has a beautifully laminated appearance, is useful as well as ornamental. It occurs in Scotland (Montrose) and Galston (Ayrshire), Brazil, and Uruguay, and is chiefly worked in Germany (Oberstein).

Agate is used for the knife edges from which accurate balances are suspended since it is not affected by the atmosphere and is very hard. It is also used for pestles and mortars which are to be used for grinding up hard substances. Agates for jewellery are doctored or worked by taking advantage of the fact that its laminae are not equally porous and causing them to absorb various colouring matters.

**TOURMALINE** is a highly complex boro-fluo-silicate which exists in several forms, varying from colourless to black, many of which are used as jewels, *e.g.* peridot (Ceylon), a yellow green stone, rubellite (Siberian ruby, from Ceylon, Siberia, and U.S.A.), Brazilian emerald, etc., and a colourless variety called achroite.

All kinds of tourmaline, except achroite, are very dichroic, and use is made of this property in optical instruments, although tourmaline has now been largely superseded by calcspar.

**JET** is a kind of black lignite which, when specially hard, is used for ornamental purposes. It is obtained from N. Germany, France, and Whitby (England).

**AMBER** is a fossil resin which has been highly prized from very early times. It is found in remains from the Stone Age. The Romans opened a trade route over the Brenner Pass to the Baltic so as to secure a supply, and before that caravans used to take it

to Babylon from the Baltic, whilst in the Middle Ages the Arabs transported it from the Baltic to the East.

Amber is found on the shores of the Baltic, whence it has been washed out from the clays and sands which form the shore. It is transparent and brittle, and when rubbed develops electricity. This fact was known to the Greeks, and it is from their word *electron* = amber, that the modern word "electricity" is derived.

Amber is used for beads, mouthpieces for pipes, etc., but most of the alleged amber is manufactured from camphor and gums or "reconstructed" by fusing amber chips under pressure. Amber is sometimes dissolved in alcohol in the manufacture of expensive varnishes.

**KAURI GUM.**—Somewhat similar to amber is the kauri gum of New Zealand. This is a fossil gum from the kauri pine. It is located in the earth by means of a spear whereby the hard nodules which it forms can be recognized. It is then dug up. Kauri gum is used in the manufacture of good quality varnishes.

**PEARL** is a form of calcium carbonate found in oysters from tropical areas, *e.g.* the Persian Gulf, Ceylon, West Indies, Australia, etc. The oyster is attacked by an organism and to protect itself deposits layers of calcium carbonate around the parasite. Many other shell fish make pearls, but only those from the pearl oyster and certain mussels are of commercial importance. Certain fish, *e.g.* file fish, feed on the pearl oyster, and determined efforts were made to destroy them, but it was found that with the destruction of the enemies of the pearl oyster the supply of pearls got markedly less. The problem was solved by the natural scientist who discovered that the early part of the life of the parasite which promoted the formation of pearl was passed in the stomach of the very fish which was the pearl oyster's chief enemy. Hence extermination of the file fish meant extermination of the parasite and of the pearl, so he is now tolerated and his depredations endured.

In China pearls are "manufactured" by introducing irritating particles into the shells of certain fresh water mussels. The mussels deposit layers of calcium carbonate round the particle, producing a pearl.

Pearls have been valued from early times, *vide* the story of Cleopatra and the pearl. Their beauty is due to the fact that

interference colours are produced between the extremely thin layers of calcium carbonate which form the pearl. These colours are similar in origin to those seen when a thin layer of oil floats on water or to those in a soap bubble.

**MOTHER OF PEARL** is the lining of the shell of certain oysters. Most shell fish form mother of pearl but only in one of the pearl oysters is it sufficiently thick to be valuable. Mother of pearl is also "manufactured" by the Chinese by the introduction of figures, etc., into mussel shells, which become plated over.

The pearl oyster is obtained by divers who cut them away from the beds. Native divers, without any artificial breathing apparatus, can reach depths up to 35-40 ft. and stay under water up to 1½ minutes. It does not seem as though dredging will be possible since it would disturb the young oysters and probably kill them.

## SECTION III—FOODSTUFFS AND DRUGS

### CHAPTER XIV

#### CEREALS

CEREALS are cultivated grasses, the name itself being derived from Ceres. Many cereals have been in cultivation from prehistoric times, so long that in most cases the particular grass from which they have been bred is not to be identified, though this is not true, perhaps, of oats. Cereals form the most important element in the diet of man, though the particular cereal in use in any given area is variable.

Cereals not only form the staple diet of man but they are extremely cheap as compared with animal food. If the tables of nourishment can be believed, meat nourishment is ten times as dear as wheaten bread nourishment from the weight point of view.

**WHEAT.**—The most nourishing of all the cereals, as well as the most palatable, is wheat. Wheat has been in cultivation for ages, and samples of it have been found in the remains from the lake dwellings of Switzerland. It was a staple crop in ancient Egypt, and appears to have come originally from Asia, probably Mesopotamia.

Wheat is best grown in temperate climates, although it will do well in the tropics in elevated regions without too much harvest-season rain. A study of the Board of Trade returns reveals the fact that Britain imports wheat harvested in every month of the year and from many different parts of the earth : United States, Canada, Argentina, India, and, in normal times, Russia, Siberia, and Rumania send the chief supplies, but some comes also from Chile, Australia, and Egypt. Wheat is an important crop in England and Scotland. Countries with a big wheat production, but not for export to Britain, include France (which produces more wheat than Canada), Germany, Austria, Hungary, Belgium,

Spain, and Italy. All of these, be it noted, are western European countries.

The conditions best suited to the growth of wheat are a clayey undulating soil with spring rains and a sunny time from one month before the harvest onwards, which time also should be quite free from frost.

There are many different kinds of wheats, but they divide roughly into two classes, hard or strong, and soft or weak wheats. Of these "hard" wheats are much the better for bread-making, since soft wheats when milled, make a dough of so "fluid" a consistency that the carbon dioxide gas, produced by the growth of the yeast in it, escapes, and the bread is heavy in consequence. This was one of the defects of "war bread." Good hard wheats need a hot sunny dry summer, and grow well in Canada and India. They have not until quite recently been well grown or much grown in England.

The British farmer, who is, to say the least, not a philanthropist, has been only concerned about immediate gain, and since the greatest yields have been from soft or weak wheats he has grown them without much attempt at trying to farm better varieties.

Wheats have been produced in England, however, which possess many desirable qualities, including strength, and a brief summary of their production seems desirable.

Mendel discovered, some time ago, that if certain different peas were crossed and recrossed the eventual offspring were of four different forms. One form resembled one parent, another form resembled the second, whilst the other two forms contained some of the properties of each original ancestor. In the following scheme small letters refer to colours and capital to shape. The parents were then aA and bB, whilst the descendants were respectively aA, bB, aB and bA. That is to say, two new peas had been produced. This is not only true for peas but throughout the whole natural world.

Therefore it would appear to be possible to produce from a red strong wheat and a white weak wheat, red weak wheats and white strong wheats, and this is what Professor Biffen, of Cambridge University Plant Breeding Institute did. After much experimentation crosses of Canadian hard wheats, which remained hard when bred in this country, with English soft wheats, which are



heavy croppers, have been produced, and these crosses in certain cases breed true, crop well, and are hard wheats, very good for bread, and with strong straw capable of resisting much wet weather. The continued application of this principle opens up a new field in agriculture, both as regards crops and stock, and there seems no reason why, in the future, any desirable inheritable property possessed by one species of a group should not be added on to some other desirable characteristics of some other member of the group. Thus, in the future the highest yielding wheats, for instance, may be also the best quality wheats and be grown in England.

The wheat known as Burgoyne's Fife was produced at the Plant Breeding Institute as the result of crossing a Canadian strong wheat, "Red Fife," with an inferior English wheat, Rough Chaff. Burgoyne's Fife is a strong white wheat which crops very well in certain areas. Moreover, it ripens quickly and can therefore be sown in the spring. Better wheats are promised.

Another important result of Mendelian breeding is that varieties which are immune from epidemic diseases can be produced. Thus wheats which are not attacked by rust and yet yield well, and potatoes which are immune from wart disease, have been produced. Whatever may happen in the future, however, the great bulk of English wheats at the present time are soft, and the millers are bound to admix more expensive foreign wheats in order to make good bread flour.

As is to be expected, the yields of wheat are highest where land is most expensive, *i.e.* where most must be got out of the land by manuring, etc. Thus, whilst in Australia the yield may be less than 5 bushels per acre and in India 9, the average yield for England is 30 bushels, and in selected areas as much as 60. Compare this with the average 10 bushels of manorial England when land was cheap.

Wheat is manufactured into various pastes, especially in Italy. Inferior hard grain can be used, which in Italy is grown in Tuscany, or it may be imported.

The best known of these are macaroni, vermicelli, spaghetti, and semolina. In the first three substances a thick paste is made with wheaten flour which is then pressed through dies. The paste

is then heated and dried. The centre of the industry is Naples, but much is now made in Japan. Semolina is usually coarse ground wheat but may contain other cereals and potato.

Extremely important in connection with wheat is the straw, and in Tuscany wheat is even grown mainly for the straw. To do that it is planted very close together. This is the basis of the Tuscan straw industry and "Leghorn" hats. The grain may be used for wheat pastes, but some of it is fed to poultry (Leghorn fowls).

The world's annual wheat production is supposed to be about  $5\frac{1}{2}$  billion bushels, of which the U.S.A. raises normally 1,000 million bushels.

**BARLEY.**—Barley has in the past been a very important crop, especially in those countries whose summers are too short and sunless for the production of good wine grapes. Until quite recent times the standard drink in such cool temperate countries has been beer, and nearly all beer is made from barley.

Barley is of two chief kinds, one with two rows of grain in the ear and one with four. Barley does best on fairly light chalky soils. It is a spring crop and can be sown very late since it matures more quickly than any other cereal which ripens in Britain, being ripe in about fourteen weeks after sowing. Barley cannot be harvested until it is dead ripe, since its chief use is for malting, and if it were not ripe this would take a variable time, which would be extremely undesirable. Barley meal is used for pig-rearing, being a very fattening food, whilst it makes a very good sweet bread which, however, does not rise very well and is not suited to the present palate.

Barley grains, with the husks removed, are much used for broth-making, and when the outer skin is removed as well pearl barley results. Barley meal is used in the preparation of barley-water, which renders milk much more digestible, and is used for that purpose for invalids and babies.

An average yield of barley in England is about 35 bushels per acre. It is grown also in Germany, Austria, Russia, Scandinavia, China and Japan.

**OATS.**—Oats do not appear to be of such antiquity as wheat and barley. There is, for instance, no mention of them in the Bible, although that may be because in general they do not do at

all well in hot climates, and so may have been unknown in Palestine although existent elsewhere. They are not grown in Spain or S. France. Although oats will grow on poor soil, nevertheless they yield best when the ground is good. They like best a cool and moist summer and hence are particularly suited to cool temperate regions ; they can be cultivated to within 200 miles of the Arctic Circle.

Oats ripen slowly but can be cut somewhat green. Their chief use is as a fodder crop and especially as a horse feed. Oaten flour, or the clean rolled grain, is much used for making porridge, which is almost a staple food in Scotland and much eaten in England and Ireland. Oats are grown chiefly in the U.S.A., Russia, and Northern Europe.

**RYE.**—Rye is a cereal crop little grown in England, although at one time it was fairly extensively cultivated. It is, however, an important breadstuff in Russia, where it is the staple food, in Scandinavia and in eastern Germany. Rye bread is "black" but nutritious. The continued use of rye appears at times, however, to produce a pathological condition known as ergotism. This is due to the fact that rye is subject to a fungoid disease. A preparation of the infected part, "ergot of rye," is used medicinally because of its stimulating effect on the involuntary muscles. It is especially used in obstetrics to hasten birth. Rye grain is also used in the preparation of spirit, vodka in Russia and whisky in U.S.A.

Rye takes a long time to mature, but is very hardy and can be grown as a winter or spring crop. Rye straw is tough and can be used for braids for hat making. It is sometimes used for preparing a coarse rope.

**BUCKWHEAT.**—Buckwheat is not a grass but is cultivated somewhat similarly. It is of value since it matures very quickly and so can be planted where another fodder crop has already failed. It is used for feeding cattle and poultry and the flour for buckwheat cakes. It is grown principally in Japan, Russia, France, and U.S.A. In England it is never grown, unless a grain crop has failed in spring due to frost or some other cause, as it need not be sown till the end of May.

**MAIZE.**—Maize, although not a tropical plant, requires warmer conditions than the cereals already considered. Like them, however,

it is a true grass. Unlike wheat it cannot stand frost at any time and so must be planted too late to mature in England. Again, unlike wheat it requires rain right up to the harvesting if it is to do well. It is remarkable as being the only cereal indigenous in North America ; it is native, however, as well in the East Indies. Maize is grown principally in U.S.A. (middle states, such as Illinois, Kansas, Ohio, etc.), Argentina, Mexico, Austria, Hungary, Rumania, the Balkans, Russia, Italy, Rhodesia, etc. It is grown in Sussex and some other parts of southern England to be cut green for fodder. It is sometimes stacked green to be kept for a winter food for cattle (ensilage).

The effect of summer rain is shown by the fact that recently in Argentina in two successive years, the first of which had a dry, and the second a reasonably wet, summer, the crop in the second case was over ten times what it was in the former.

Maize is an important article of human food in many countries, southern U.S.A., Mexico, Italy, Rhodesia, etc., but seems to be extremely unpalatable to the English people. The cobs can be eaten as a green vegetable when unripe and bread flour can be made from the ripe grains. In Italy a porridge, "polenta," made from maize, forms the staple food, but is supposed to be responsible for a loathsome skin disease, "pellagra." Pellagra is, however, also known to be distributed by certain sand flies. As a breadstuff maize flour is deficient in that it will not "rise" well.

Maize is especially important as a pig, poultry, and cattle feed, and the tremendous Chicago pig industry is, in the main, based on the maize of the adjoining states. Good bacon, however, does not appear to be possible from "corn" fed pigs.

Maize is much used in the preparation of starch, and the seeds are also crushed on a very large scale for oil, used in paints, soap, and in making artificial butter. The crushed cake can then be used as a cattle food. The grains are also used in making "corn" whisky, and the pith has been used in making ships torpedo proof, since it swells greatly on contact with water.

**MILLET.**—Millet is one of the cereal grasses which can be grown under tropical conditions, even when rain is lacking, and it will also do well in poor sandy soil. It is therefore of prime importance as a staple food in certain parts of Africa, China, Japan, and India.

Millet is grown as a fodder crop in Europe. It attains a height of 12 ft. Sorghum is a special variety of millet.

**DURRAH.**—Durra is the most important of all African "flour" plants. It grows up to 8 ft. high and its tiny seeds can be used in the same way as rice, or when ground furnish an inferior bread.

The well-known Kaffir corn (*Sorghum cafrorum*) is one of the best known durrahs. Another durra, or sorghum, is brown corn, or sugar corn, from the stalks of which sugar syrup is made in India, China, Japan, and U.S.A. Sugar corn syrup is very difficult of crystallization.

**RICE.**—Rice, although not so important a tropical food as millet and its congeners, is nevertheless a staple food over very large areas. Rice is a true grass, which requires a long frost-free period of growth, it will not therefore mature in England. In addition, rice likes an abundance of water, it is thus an ideal grain for monsoon regions.

The typical rice fields, "paddy fields," are indeed flooded during part of the season of growth, and the writing of Isaiah, "Cast thy bread upon the waters and it shall return again after many days," is an allusion to the practice of sowing rice in the actually flooded paddy fields. It is well known that cereals yield better the nearer they approach their cold limit of growth, and this is true of rice, the finest in the world being grown in northern Italy under the shelter of the Alps. Rice is also grown in the Banat in Hungary. The great rice-producing countries of the world are, however, China, Japan, India (especially in Bengal), all other parts of S.E. Asia, south-eastern U.S.A. (Texas, Louisiana, Carolina, etc.), and central and northern South America.

The cultivation of rice, as carried on in Japan and China, entails an enormous amount of labour, as in order to check the attacks of parasites it is first sown in seed beds and then transplanted. (It is interesting to note that the onion fly is rendered comparatively harmless to onions by the process of transplanting.) In the East, also, rice is reaped by hand, the reaper taking a few stalks in his hand and cutting them through with a knife.

As a staple diet rice is very deficient in nitrogenous foods, but contains a large percentage of starch. After the husk is removed by milling the rice grain is polished by a further milling process. Now it is believed that the disease called beri-beri is due to living

on an exclusively rice diet, and recently it has seemed as though polished rice is much more likely to produce the disease than unpolished rice. In any case, hens fed exclusively on polished rice contracted the disease much more readily than hens fed on the whole rice, and further, the addition of an infusion of the outer husk to hens with beri-beri seems to be very beneficial to them. If this is the case stringent legislation should be adopted to make the polishing of rice illegal, since beri-beri is one of the great scourges of man in the East. The husk of rice is used as fuel, and the straw for mats, ropes, bedding, etc. Rice-paper, however, is not made from rice straw, but from the pith of a Formosan tree (*Fatsia Aralia papyfifera*), which is removed, cut and pressed.

Rice is used in the preparation of starch, and from rice the Japanese produce their national intoxicating drink, *saké*.

Neither the millets nor rice take anything like the place in commerce which might be expected from their production and consumption because they are not much transported, being used locally.

## CHAPTER XV

### VEGETABLE FOODSTUFFS OTHER THAN CEREALS

**BEANS AND PEAS.**—After cereals the most important vegetable food stuffs are probably the beans, and as vegetables they are particularly valuable because of the very high percentage of nitrogenous food which they contain. In this respect they approach meat, and they form the usual substitute for meat in a vegetarian diet. Beans are staple articles of food in many countries which have a low standard of living, especially in China and Japan. In these countries they are usually eaten in the form of a curd and this may be the chief dish at every meal. Tortilla beans are the most frequently taken food in Mexico and other parts of Central America, whilst the dried haricot is of great importance in Southern France.

The beans most frequently grown in England are scarlet runners, dwarf beans, broad beans, and a variety of broad bean used as fodder, called horse beans. The haricot is grown in France and U.S.A., and other varieties in Africa, China, etc. In most English-grown beans the pods as well as the seeds are eaten, but in dried beans the seeds only are consumed.

The soya bean, which is grown throughout south-eastern Asia, is of great importance for the oil which is expressed from it. The cake left is a cattle food. In Japan soya beans are fermented to produce a sauce which may be kept for years like wine in Europe. It is put on the table at all Japanese dinners except the poorest. None of the English beans are hardy except broad beans, and so with that exception they form a summer crop. Fortunately they mature very rapidly.

Beans as well as peas are a good crop to grow, inasmuch as the roots have little nodules which are colonies of nitrifying bacteria, *i.e.* micro organisms which can convert atmospheric nitrogen into a compound which can be assimilated by plants. Thus, in certain respects, ground is improved by cropping with peas and beans.

**Peas** are closely allied to beans, and like them, have been in

cultivation from the earliest times. They are grown in most parts of the world. The unripe seeds are usually eaten, although the ripe seeds are threshed out and used dry throughout the year. The green seeds can also be preserved. Peas are hardier than beans and are in full season earlier, although a great deal has been done by cultivators in extending the harvest season.

**Lentils** are the dried seeds of a plant allied to the pea which is grown in Mediterranean countries, *e.g.* Egypt. Lentils have a particularly high nutritive value, especially in casein.

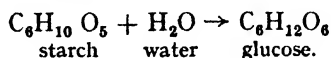
**Vetches** are also members of this family of plants (*leguminosæ*), and are grown as fodder crops and with intent to improve the land for some subsequent crop.

**TAPIOCA.**—Tapioca is prepared from the tubers of the manioc or cassava plant grown in tropical South America, tropical Africa, and tropical Asia. The tubers are poisonous, but when macerated with water, or heated, the poison is removed. Locally the tubers are eaten as a vegetable, or after drying they are grated and made into a sort of cake (cassava bread). Tapioca is the starch from the tuber prepared by pounding up with water and drying.

**SAGO.**—The pith of a palm tree grown in tropical Asia and the tropical Pacific Islands. The starch is prepared by washing and drying the pith.

**SUGAR.**—The sugars are crystalline substances (carbohydrates) found free in the saps and juices of various plants, and in milks. Chemically the sugars are closely allied, their chief differences often being physical. The most commonly distributed sugar is glucose, which is found in most ripe fruits and in honey, whilst it results from the hydrolysis of most starches, and in combination in the large class of bodies known as glucosides, *e.g.* indican, the mother substance of indigo.

Glucose is prepared commercially by the hydrolysis of starch with sulphuric acid. The sulphuric acid is neutralized with chalk and the resultant calcium sulphate filtered off. The solution of glucose which forms the filtrate is then evaporated at a low temperature to avoid charring and the glucose separated out as a semi-crystalline looking mass.





Glucose solution prepared as above is much used in brewing, and glucose itself is used in making jam where, since it is fermentable, it should only be a small percentage of the total sugar used, and in confectionery. It is also powdered and mixed with cane sugar as an adulterant, and since it is only about half as sweetening as cane sugar this is greatly to the disadvantage of the consumer. Strong solutions of glucose are sold as syrups for domestic use.

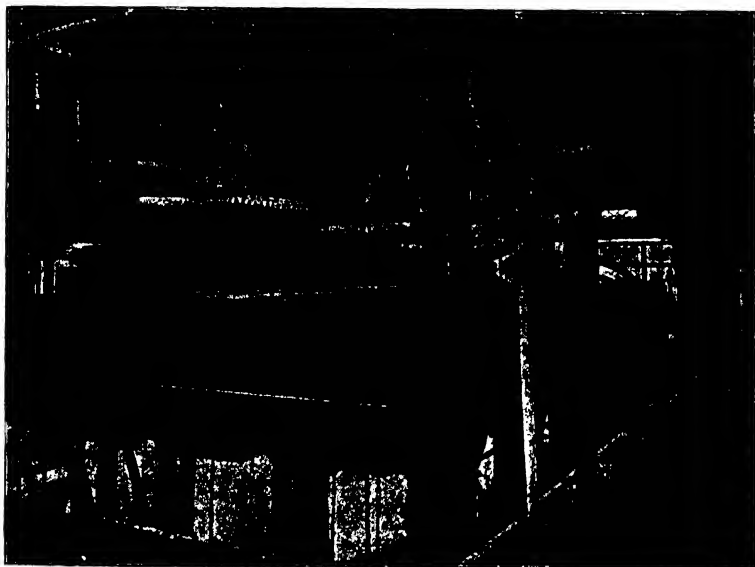
**Saccharobiose, i.e. Cane and Beet Sugar.**—Cane and beet sugar, which are absolutely identical, are one of the many possible sugars of the empirical formula ( $C_{12}H_{22}O_{11}$ ), and when sugar is spoken of it is usually this particular sugar which is meant.

**Cane Sugar.**—The sugar cane is a tropical grass which cannot stand frost, therefore, since a great deal of hand labour is necessary in its cultivation, it can only be grown where coloured labour is cheap and plentiful. At one time the great importance of the West Indies to Britain was because of the sugar they exported, and it was principally to provide the labour necessary for the cultivation of the sugar-cane that first negro slaves and then white ones (in the form of British convicts) were imported into the West Indies in large numbers.

Sugar cane is cultivated in India, China, Java, East Indies, Cuba, West Indies, Mauritius, Natal, Queensland, southern U.S.A., and north S. America. The sugar cane is grown from cuttings, since as a result of ages of cultivation, it no longer produces seeds. Generally speaking, the practice of continually rearing plants from cuttings is bad. For one thing it perpetuates disease and weakness, and improved varieties cannot be produced; and judging from the results obtained in the garden (with ordinary verbena, for instance), it might be highly profitable to try and rear sugar cane from seed again and exercise artificial selection on the plants so raised. At present botanists are engaged on this problem, and although nothing of commercial importance has yet been achieved it is quite likely that the investigation will prove a commercial success. The cuttings when planted out grow under the appropriate conditions of great heat and much natural moisture, or irrigation, at a very rapid rate, and since they are gross feeders the land should be very liberally fertilized. In the past this has not been done,

and the yield has very much suffered in consequence. In the more scientifically conducted plantations in the U.S.A., sugar cane is only grown about two years in three, a rotational crop of maize or legumes being sown in the third year.

When the canes have matured they are cut near the root with sharp knives or hatchets and carted to the factory. The roots



INTERIOR OF SUGAR FACTORY

which are still left in the ground, like the roots of many grasses after cutting, throw up fresh shoots (ratoons) which also produce sugar. In some areas this is carried on year after year, but it has the great disadvantage of encouraging insect pests, particularly the harmful white ant in India.

The first process of manufacture is to crush the canes between rollers, whereby the sap is expressed. The solid refuse is used as fuel in the factory. The sap is immediately heated to such a temperature as will sterilize it and so prevent fermentation, and then passed into a copper vat, where the acids which the sap contains are neutralized with slaked lime. The vat is now steam

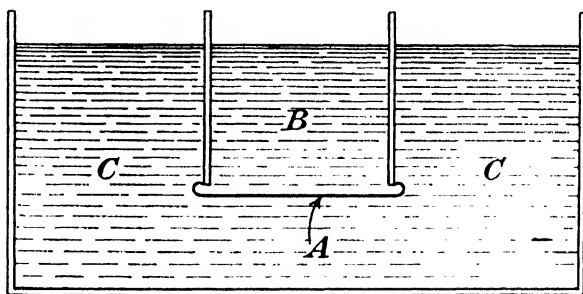
heated until the sap is at a temperature of about 90° C., when a scum and dregs form. The middle layer of moderately clear sugar solution is drawn off and further clarified. It is then filter-pressed and evaporated, usually under reduced pressure which economizes fuel and prevents charring, till, when allowed to stand, it will crystallize. The sugar so produced can be purified by reboiling with blood or bone charcoal, to remove colour, and recrystallizing. This may be repeated many times, the sugar becoming progressively lighter in colour until white. The sugar thus produced is dried, exactly similarly to the way clothes are dried in a laundry, by being whirled round in a centrifugal machine at a very rapid rate. The mother liquors from these successive crystallizations, when no more sugar can be extracted, are known as treacle and golden syrup. England is the centre for cane sugar refining.

**Beet Sugar.**—During the Napoleonic wars, as a consequence of the British blockade, sugar, which was then a purely tropical product, could not be obtained, except at famine prices, in Europe, and Napoleon offered prizes for the production of sugar from white beet or any other continental source. The process of extraction was costly, but beets with gradually increasing yields of sugar were bred and cultivated, and now the sugar beet produces more than one-third of the world's sugar supply. The sugar beet is cultivated in Holland, Belgium, N. France, N. Germany, Austria, Russia, and U.S.A. It seems to do best under strictly temperate conditions, and undoubtedly does well in England, but since its cultivation entails much hand labour it is not grown here. If a good machine "puller" of the roots were to be invented sugar beet would probably be an important crop in England. An attempt to persuade Cornish farmers to guarantee a definite acreage to beet, to be supplied to a proposed factory in west Cornwall, failed owing to the ignorance and conservatism of the farmers, who would not give the scheme a trial.

The beets, wherever grown, are harvested by hand just before the frosts, and the leaves are then twisted off, also by hand. They are then taken to the factories, which are usually dotted about the beet fields. Those beets from which the sugar is not immediately to be extracted are clamped until required.

The extraction of the sugar from the beet depends upon the operation of dialysis.

**Dialysis.**—If over one end of an open glass cylinder (B) a piece of parchment (A) be stretched and fixed, and the cylinder, after having sugar or salt solution poured into it, be immersed in a trough of water (C), sugar or salt will pass through the parchment A into the water in C until the strengths of the solutions in B and C are the same. If, during the operation, the solution forming in C be constantly replaced



*A* = a sheet of parchment.

*B* = a vessel closed at the bottom by the parchment sheet *A*.

*C* = a larger vessel containing, at the start, water.

If into *B*, at the start, were placed a solution of sugar and gelatine, after a time a solution of sugar only would be found in *C*.

#### DIALYSIS APPARATUS

by fresh water all the sugar or salt can be removed from B, and this is true for solutions of all crystalline solids, which are called crystalloids. If, however, instead of sugar or salt a solution of a non-crystalline substance like gelatine or starch had been placed in B practically no gelatine or starch would find its way into C, and this is true for all similar substances, which are called colloids. Now suppose that a mixture of gelatine and sugar solution had been placed in B; the sugar would pass through the parchment, and by repeated renewal of the water in C all the sugar could be removed from B, but practically all the gelatine would remain in B. Now the cell walls of plants, and therefore of sugar beet, behave similarly to parchment with regard to crystalloids and colloids. The principal crystalloid present in the cells is sugar, and the

remaining substances, apart from water, are colloids, so that if the beets be allowed to stand in water all the sugar can be removed from the cells, but practically nothing else.

The beets, therefore, after mechanical washing are sliced by machines into very thin narrow strips, and these are introduced into a series of warmed tanks, into the first of which water is passed. By osmosis this water passes into the cells containing the sugar and the solution is then dialyzed out. The solution from the first tank passes into the second, and so on. The crude sugar solution so obtained is, like cane sugar solution, treated with slaked lime. This causes much of the impurities present to rise to the surface whilst any calcium saccharate formed is decomposed into sugar and chalk by passing carbon dioxide through the solution. The impurities and chalk are filtered off and the process repeated until the solution is nearly pure. The solution is evaporated and blood charcoal added to remove colouring matter, and then further evaporated in vacuum pans until crystallization sets in. The crystals are dried in centrifugal machines. When white sugar is desired, the first sugar obtained is redissolved, further bleached with blood charcoal, and recrystallized. The solid refuse from beet from which all sugar has been extracted is dried and used as cattle food.

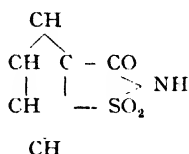
For a time it looked as though beet sugar would be successful in removing cane sugar from the market, but improved methods of cultivating the cane, and the abolition of the old wasteful field factory system of crushing the canes, have enabled cane sugar to compete on good terms with beet. Indeed, it is probable that cane sugar is the more cheaply produced, since the Dutch have found it necessary to restrict the output in Java in order to protect their own beet sugar industry.

As previously mentioned, glucose, or grape sugar, is a frequent adulterant of cane sugar. Its presence is detected by the saccharimeter, since the two sugars twist the plane of polarized light through different angles. The angle through which the plane of polarization is revolved furnishes very simply the percentage of glucose in the sugar.

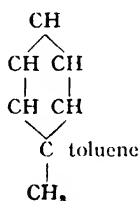
Other sugars are employed locally in different parts of the world. Corn sugar has already been described, and in Canada and

north-eastern U.S.A. sugar is prepared from the sap of the sugar maple, whilst jaggery is a sugar prepared from coconut palm.

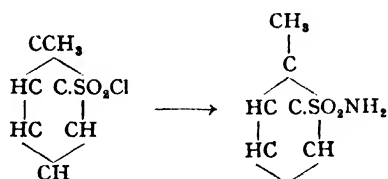
**SACCHARINE.**—Saccharine, which is the imide of ortho sulpho benzoic acid



can be prepared in various ways, one of the most used of which is by heating toluene with fuming sulphuric acid and neutralizing with calcium carbonate. The calcium benzene

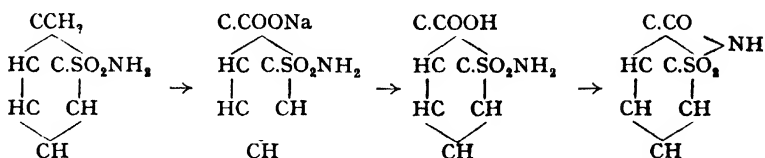


sulphonates are treated with soda, and the sodium salt converted into the sulpho-chloride by phosphorus trichloride and chlorine. The pure ortho toluene sulpho chloride is converted into the sulpho amide with ammonium carbonate—



The  $\text{CH}_3$  group is then oxidized to  $\text{COOH}$  by alkaline permanganate according to a general reaction, and on decomposing the

sodium or potassium salt with hydrochloric acid saccharin is formed.



Commercial saccharine is about 300 times as sweet as sugar, but the pure ammonium salt of saccharine (sucramine) is 700 times as sweet as sugar.

**POTATOES.**—These are tubers of which an enormous number are consumed in northern latitudes, where they supply an immense amount of starchy food. Although of tropical origin (they were introduced from America by Raleigh) they are not much used by people in warm climates, where their place seems to be taken by maize. The Italians, for instance, call the English the “potato eaters.” In Ireland and Germany potatoes are a staple food. Potatoes are rarely grown from seed but from the green immature tubers which should weigh about 2 oz. each. The plants cannot stand frost and so cannot be planted in England until about May, but fortunately they mature very rapidly indeed and can always be harvested before the frost. A fair yield is about 2 lb. per root, or about 10 tons per acre, which is thirteen or fourteen times the yield from wheat, although, of course, wheat yields straw and a higher percentage of nitrogenous food. There is a considerable industry in producing early immature potatoes, “new potatoes,” which, because of their fine flavour, are in great demand and fetch high prices. They are grown on a large scale in Jersey, Algeria, South Africa, etc., as well as alongside of maincrop varieties in all potato-growing areas. Potatoes, except new potatoes, keep from harvest to harvest and so, without special storage, form a perennial supply of food.

Potatoes are liable to epidemic diseases, in particular “the disease” and wart disease. The disease (late blight, *phytophora infestans*) can be largely prevented by spraying with solution containing copper salts whilst, although wart disease is incurable, good varieties have been bred which are immune from it. It should be

noted that potatoes are best grown in England from "seed" grown in Scotland, "Scotch seed," or grown in England from plants grown from Scotch seed, *i.e.* "once grown." Potatoes are manufactured into starch and alcohol, and inferior spirits, whilst a flour can be produced from them which can be admixed with wheaten flour in making bread.

A good diet includes plenty of green vegetables which, besides containing sulphur, also have various salts which are valuable in preventing skin disease and in keeping the blood clean. Therefore in all country gardens and in rings just outside all great towns, green vegetables, especially brassicas, such as cabbages, cauliflowers, and turnips, as well as spinach, are grown. The total production is very large, but the trade in them is not so great as they are usually consumed at or near the place of growth. Certain "greens" are grown as fodder crops, including turnips (swede and common) kohlrabi, mangolds, cabbage, etc., and form very valuable winter feed for cattle and sheep. Carrots are usually grown in a similar manner to greens. In addition to their culinary use they make an important horse feed. •

Onions, perhaps because of the difficulties which beset their cultivation, are not grown in sufficient quantity locally and so form important crops for export in certain areas, *e.g.* British Columbia, Northern Spain, and Holland. Britain buys a large quantity of foreign onions every year.

Asparagus is tinned in regions favourable to its growth (California) and exported to other countries.

**FRUIT.**—Fruit, although from its palatable nature, something of a luxury, is nevertheless, a very important item in a good diet, alike of uncivilized and civilized peoples. Fruits are rather exigent as to their conditions of growth, and so in many cases can only be grown in areas specially suited to them. At one time, therefore, the inhabitants of any area had to be content with those fruits which could be grown locally, since fruits are often of a perishable nature, but modern conditions of transport and storage have altered this, and tropical perishable fruits can now be purchased in most of the great towns of the temperate world. The importance of this trade is so well recognized that the British and West Indian Governments combined to bounty-feed shipping companies in



order to get them to fit out ships for the trade. The chief fruits imported from the tropics are grown in the West Indies, and, although the bulk of the trade goes to New York, since it is nearer, yet a good deal comes to Britain.

The chief tropical fruits imported are pineapples and bananas. Extensions of this trade can be looked for as tropical areas become more developed. Tinned pineapples come from Singapore, etc.

**MEDITERRANEAN FRUITS.**—The fruits known as Mediterranean fruits usually come from those regions with a predominantly winter rainfall, since they are all quick growers and slow ripeners. They are, however, much grown in California. The Mediterranean countries, extreme South Africa, the south of South Australia, and parts of Chile, all produce these fruits, which include the orange, lemon, peach, apricot, fig, etc., and the olive.

The olive is of particular importance in such regions, since the condition of summer drought is against good grass, and therefore against the rearing of cattle. Milk and milk products, *e.g.* butter, are therefore very scarce, and olive oil is a highly nutritious substitute. Olive oil ranks as a staple in such regions, and is constantly alluded to as such in the Bible, where "corn and oil" are synonymous with good living, and the widow's cruse of oil was an essential of existence. The finest olives are grown in Provence, in Tuscany, and especially round Lucca. Lucca oil has in consequence got to be a trade name for the best olive oil. Olive oil is used for preserving fish in tins (sardines), as well as in frying, sauces, salads, and other dishes.

Peaches, etc., although sometimes exported fresh, are most frequently tinned, especially in California.

Almonds are usually exported quite ripe, in particular from Southern Spain, but they are sometimes shipped green.

The orange is a fruit grown on a very large scale in different parts of the world, especially Spain, North Africa, Java, and California. It forms a most important item in the exports of Spain, and since it keeps well can be obtained almost all the year round in England. Certain bitter oranges (Seville oranges) are much used in the preparation of a preserve which is almost an essential breakfast article in Great Britain, *i.e.* marmalade, so called from the fact

that it was probably first prepared from the quince in Portugal (*marmelada* = quince).

Lemons are rather more exotic than oranges, and in Europe are only grown commercially in favoured spots, e.g. in the lee of the A'ps in Italy, and in Sicily. Lemons, apart from their consumption as fresh fruit and in the making of "home-made lemonade," are used in the manufacture of citric acid and in the preparation of certain essential oils. Citric acid is prepared from the lemons by expressing the juice and boiling it, neutralizing with chalk and decomposing the calcium citrate so prepared with sulphuric acid. After filtering from precipitated calcium sulphate the solution can be concentrated and citric acid crystallized out. Citric acid is used on a fairly large scale in the manufacture of lemonade powders.

Citron is also grown in the Mediterranean. The peel of citron, lemon, and orange is preserved by boiling up with sugar, and sold as candied peel.

**DRIED FRUITS.**—Certain fruits which do well under the conditions described can be sun dried, and when so treated will keep good for very long periods. They include figs and various kinds of grapes.

The most important of all is the Corinthian grape, a dwarf form which is, when dried, the most important of all the exports of Greece. Since, for a long time, these dried grapes were mainly grown round Corinth, they got to be called "Corinths," corrupted to "currants." Sultanas and raisins are other varieties of sun-dried fruit exported from California, S. Spain, and the Levant.

Figs are dried in California and the Levant and especially Smyrna.

**TEMPERATE FRUITS.**—These include apples, pears, plums, etc. The apple is largely cultivated in many parts of the world, especially in western England (Devon and Hereford), Normandy, Hungary, California, British Columbia, Ontario, and Tasmania. It is hardy, although much injured by late frost after it has blossomed. Many varieties of apple keep well, and so no special transport or storage is necessary. Apples, in addition to dessert and culinary use, are used in the preparation of jams, which are often apple jelly and some other fruit. Such jams are often sold as "improved" by the addition of other choice fruit. Cider, which is made by fermenting apple juice, is an alcoholic drink which is almost an essential in

certain localities, *e.g.* Devon and Normandy. Apples are dried for export and out of season use.

Pears grow under the same conditions as apples. They do not keep well and so, in general, only enough for use near the actual harvest time are grown. In California, however, pears are tinned and bottled for use throughout the year.

Most of the soft fruits, such as red, black, and white currants, etc., are so perishable that they can only enter into general trade preserved as jam. Plums, however, stand carriage and are grown largely in special areas, *e.g.* Serbia, Austria, South Africa, and Worcestershire.

**THE GRAPE.**—The grape is not, strictly speaking, a temperate fruit, albeit some of the best grapes are grown in temperate latitudes, *e.g.* the Champagne, where the winter is colder than in England. Grapes, as a matter of fact, are quite hardy and resist frost with ease, but they must have much hot sun to ripen them. They require, therefore, Mediterranean or continental summer conditions, and given those the kind of winter does not matter. Grape vines grow easily in England, but the grapes rarely mature and cannot compete with those grown under more favourable circumstances elsewhere. Where the grape does well it is a very profitable crop, being about four times as valuable as the wheat which could be produced on the same area.

The chief grape-growing countries are France, Italy, Spain, Portugal, Greece (currants), south-west Germany, Austria, Hungary, Algeria, California, South Australia, and Argentina.

Grapes are cultivated somewhat like hops, except that the sticks over which they grow are not nearly so high. As before mentioned, they do best when they get most sunlight and therefore grow better on the slopes of hills facing south. Since in the South of France such hills are often castle-crowned, the superior wines produced from the grapes grown on their slopes are called "Chateau —."

The vines in France have been subject to attack by blight, a species of aphis, called phylloxera. Phylloxera is mentioned by classic authors, and although many palliatives were known there were no cures. It was found that American vines grown in French soil were almost free from attack, but that the grapes produced

inferior wine. When French vines were grafted on American stock the plants proved resistant, and the grapes of good quality.

**NUTS.**—Various nuts are used as more or less luxury articles of diet, but some of them have assumed an important place in modern life because of the oils which can be expressed from them. The most important of them is the fruit of a tropical palm, the cokernut. It should be borne in mind that, generally speaking, palms will not thrive where the average annual temperature falls below 68° F., and so of necessity all palm products are either sub-tropical or tropical. They form to-day the most important tropical products.

**The Cokernut, or Coconut.**—The cokernut palm grows to a height of over 50 ft., and is crowned by about twenty or so long leaves (about 15 ft. long). It is truly tropical and almost equatorial, rarely thriving much more than 15° from the equator, but, except as regards temperature, it is not at all exigent since it withstands drought, excessive rain, or storms, and although it likes a sand soil best it will grow in others. It therefore follows that it will grow, and is grown, almost everywhere between the limits of latitude given. The cokernut palm comes into bearing when six or seven years old, and will then produce seventy or more nuts a year for more than fifty years, so that apart from the initial wait, palm plantations are cheaply run and profitable. The nuts are enclosed in a thick fibrous outer case, and when this husk is soaked in water longish fibres (10 in.) can be combed out. They are known as "coir." The coir is graded, the stiffest being used for brush bristles, whilst the chief use for the remainder is in rope-making and matting. Coir rope is particularly useful for marine work since it is strengthened by salt water. The remainder of the husk, after the valuable fibre has been removed, is used for preparing special garden soils, *e.g.* for rhododendrons, and for bulb-growing.

The nut itself contains, inside a hard shell, a layer of sweet, gelatinous matter and a liquid "milk." The gelatinous substance ripens to a hard solid, and this, when exposed to the hot sun of the cokernut palm latitudes, becomes "copra." Copra is compressed in mills, either locally or after export, and yields, when warm, coconut oil and a residue of cake which is used as cattle food. Coconut oil is one of the most important constituents of margarine, and is also

used in the manufacture of candles, soap, etc. It is a white greasy solid, smelling of coconut, and melting at the temperature of a fairly warm day, 18–19° C. Coconut oil soaps will lather in sea water, and are therefore used on board ship.

**MARGARINE.**—In the preparation of margarine *very* fresh milk is divided into two equal parts, from one of which the cream is removed. The two parts are mixed and very rapidly “soured” by bacteria. This sour milk is then churned up with a mixture of different oils, including coconut and cotton seed oils (seven in the case of the Maypole firm), which are melted and flow under gravity from cisterns at the top of the factory. The mass is then sprayed through holes in metal discs and flows into veritable railway trucks, whence it is taken to be salted and coloured. This is done on an enormous scale, and the Maypole factory at Southall has a possible output of 4,000 tons a week. The cream removed from the milk gives a by-product of 60 tons of butter weekly.

Some margarine contains some animal fat, and is then called “oleo margarine.”

From the flower bud of the coconut a liquid can be obtained, which, when evaporated, yields a sugar, “jaggery,” which will ferment in about two hours to an intoxicating drink called “toddy.” Toddy, when distilled, yields “arrack.”

The wood of the coconut palm is a valuable hard timber.

**GRASS.**—Grass is one of the most important, if not the most important, of the crops of the world. It can be grown naturally or artificially, and it should be remembered that cereals are cultivated grasses. Naturally grass grows in regions where there is not sufficient rainfall for trees and yet there is a fair rainfall, and especially a summer rainfall, *e.g.* steppes, pampas, prairies, etc. Grasses other than cereals are usually cultivated as rotation crops on mixed farms. In regions where the winters are too cold for stock to remain out of doors grass is preserved by cutting in the summer, sun-drying, and storing in ricks (hay). In parts of North America the grass is converted into hay *in situ*, as it stands (bunch grass), and since in these regions the cattle can remain out all the winter they are much cheaper to rear than they might be. Grass is sometimes stored green with other green crops, and this method is called ensilage.

## CHAPTER XVI

### FOODSTUFFS OF ANIMAL ORIGIN

**FISH.**—Foodstuffs of animal origin include those from land and water animals and, of course, also from birds. Of these the cheapest from the point of view of nutriment is fish. Even now, after the war, herrings can be bought comparatively cheaply in London, and are certainly the cheapest food in the market. Two a day are said to furnish sufficient animal body-building material (protein) for a man in normal work. Herring, and certain other fish, *e.g.* salmon, also contain fairly large quantities of fat.

Fish are as a rule easily digested, and are especially valuable as a diet in hot countries, but on the other hand there is probably no truth at all in the prevalent idea that fish is a brain food. It is based upon the old ideas that phosphorus was the essential brain food, and that fish contain much phosphorus (since they are phosphorescent). Neither of these is particularly true, and fish is no better and no worse in this respect than many other foods. It is thought that leprosy is caused by too exclusive a fish diet, and certainly leprosy is more prevalent in Norway than in any other European country, and, of course, Norwegians are a typical fish-eating people. Also fish is excluded from the diet in some hospitals for skin diseases.

Fish should be cheap because they have in general required no breeding and no feeding whilst, as opposed to the land wild animals, which are always extraordinarily dear to transport to populous areas, they can to a great extent be distributed by water, which is the cheapest of all transport. No elaborate plant is necessary for the taking of fish, although it may be used, and so fishing has been carried on by all kinds of men through all the ages of man.

Although it is generally true to say that there is no expense involved in breeding fish, yet in certain cases fish are reared artificially, especially for inland waters, and in one case a great sea fishing industry has been artificially established, *e.g.* the shad fishery of the Pacific coast of the U.S.A. It may well be that in the future the increased price of meat that is almost bound to result

from the enhanced value of land that will follow on the normal increase of the world's population, will result in a more than normal increase in the consumption of fish, especially as this would be greatly encouraged by improved transport. If this should be the case it is probable that artificial methods of maintaining the fish supply will be resorted to generally. At the present time, however, this is not necessary. The period of the war was practically a close season for many fisheries.

Although fish may be caught almost anywhere in the sea, yet certain natural conditions are necessary for a great fishing area. The chief of these are not too cold and not too hot a temperature, shallow water (banks), and a supply of fresh terrestrial mud, which contains the food for the small organisms on which the lesser fish feed.

There are three especial areas in which these conditions are fulfilled. They are the North Sea, Newfoundland, and the adjacent coasts of Canada and U.S.A., and the Yellow Sea area of the Pacific. To the first and third of these mud is mainly brought by rivers, whilst in the case of the N.W. Atlantic the residue from melting glaciers is the chief source of food.

These fisheries employ very large numbers of people, and Lyde states that 40,000,000 people, *i.e.* more than the whole population of Great Britain, are engaged in the fishing industry in China alone.

The chief commercial fisheries are the cod, the herring, and the estuarial and riverine salmon fisheries. Fresh cod is of poor dietetic value, being totally deficient in fat, but the other two fish have a very high food value indeed. Cod frequent coldish water, and are caught off the coast of Norway and on the Newfoundland banks, as well as off Iceland, usually on hooks. Boats from Granville (France) and Gloucester (U.S.A.) leave their ports in the spring and remain away for seven or eight months. They are victualled by visiting steamers. The fish caught are cleaned and salted each evening, and when a full load is obtained the boats race off to the markets. In Europe these are the Roman Catholic countries of the south. The oil from the liver of the cod is used as a medicinal food. In Norway the cod are often dried on stakes (stock fish).

The herring likes medium-temperated water, the chief European centres of the fishing being Bergen, Yarmouth, Grimsby, etc. It is best caught in the autumn, but can also be caught in the spring. It is also fished in the Bay of Fundy and the north-east coast of U.S.A. and south-east coast of Canada generally. Herrings are preserved by salting, by smoking whole (bloaters, etc.), by splitting and smoking (kippers), and by tinning. Herrings are caught in nets of different kinds, as also are mackerel, pilchards, etc. Flat fish are trawled for, nowadays usually by steam trawlers. Sardines are caught off the north-west coasts of France and Spain, in the Mediterranean and off California. They are always tinned in olive oil or cotton-seed oil. A good deal of mystery surrounds this fish, and there have been several claimants to the title (especially young herrings), but the authentic sardine appears to be a young pilchard.

The menhaden is fished for off the New England coasts, and is used mainly for its oil and as a manure.

The great commercial salmon fisheries are on the Pacific coast of northern North America, although large catches are made in similar latitudes elsewhere, *e.g.* Japan, Siberia, Norway, and even Scotland, Ireland, and Wales. The salmon was an important English fish until the pollution of the rivers drove it away. The salmon has a rather complicated life history, but the chief facts are that it is born from eggs laid in clean, running fresh water, spends most of its life in the sea, but at the age of about four years and onwards ascends a river (probably the natal river) each year to spawn. It is when they start to "run" from the sea to the spawning ground that they are in prime condition and are caught in vast numbers. But rivers are so easy to net that, in the absence of destructive floods, it can be made almost impossible for the salmon to breed, and some of the Pacific rivers are already showing signs of exhaustion. If the industry is to continue the fish will have to be preserved very rigorously and close seasons much extended. The salmon when caught are usually cleaned, cooked, and tinned, although the practice of refrigeration of the raw fish is having a rapidly increasing application. This is true also of much other fish and must have a very marked effect in future upon the problem of feeding the world's population.



The sturgeon and other fish found in the Volga and the Caspian have made Astrakhan an important fishing centre. The salted row of the sturgeon is sold as "caviare."

Certain shell fish are of commercial importance, and the oyster is very carefully bred in suitable waters. For its successful culture abundant soft mud is required, such as is found in the tidal waters at Whitstable, Colchester, the Dutch coast, New England, etc. The oysters, as they mature, are dredged and either sold alive or canned. They are of very low dietetic value (according to quotations by Hutchinson, *Food and the Principles of Dietetics*, 123 oysters contain only as much nourishment as a pound of beef, and oysters contain 88.3 per cent water). Raw live oysters are, however, very easily digested. Since oysters are eaten unsterilized they are liable to communicate disease, especially typhoid, but keeping for about two days in clean salt water is usually sufficient to render them innocuous.

Lobsters, crabs, crayfish, prawns, shrimps, cockles, mussels, are other important shell fish, some of which are canned for preservation and export. Cuttlefish furnish sepia, and trepangs (sea slugs) and sharks' fins are fished in the South Seas and exported to China.

Other industries that can be included under the head of fisheries are whaling, sealing, and sponge fishing.

The whales are of two classes, the toothed whales and the toothless or whale-bone whales. Most of them are hunted for their fat, which is run down for oil. The toothless whales have plates in the roofs of their mouths for straining out the organisms on which they feed from the water. These plates are the whalebone of commerce. In the head of the sperm whale is spermaceti, which furnishes a high grade oil, whilst the intestines contain ambergris, which is used in perfumery.

Seals are used by the Eskimos and other arctic peoples for food, but the chief commercial use is of the fur seal for its pelt.

The bath sponges are specialized members of a great family of sponges. The commercial article is the soft "skeleton" of the animal which frequents warm shallow waters. Sponges are dived for or dredged in the eastern Mediterranean, the Red Sea, the Bahamas, etc. The soft skeleton is washed and treated with dilute glycerine.

Attempts to cultivate sponges off the coast of Florida, etc., have not been commercially successful.

Before leaving the subject of fisheries it should be noted that they have an additional importance, inasmuch as in many cases they form a cradle for the mercantile marine and for navies. This is so well known that some governments, *e.g.* France, have offered bounties to men engaged in sea-fishing.

**MEAT.**—Foods of animal origin are the best of all those used by man. Although, of course, other things besides meat, etc., are necessary to a perfect diet, without a sufficiency of animal food men are stunted and of light weight, *e.g.* monsoon Asiatics. Animal foods other than fish can best be divided into three classes, *i.e.* (i) flesh, (ii) milk and milk products, and (iii) poultry and eggs.

(I) **FLESH.**—Flesh is an expensive but valuable food. It contains much protein or cell-building matter, and, if the animals have been properly fed, a considerable amount of fat. Meat is easily digested in the stomach only and therefore does not overload the intestines. Lean meat is rather more easily absorbed than fat meat, and tender meat than tough. It is important to note that fat meat is cheaper than lean meat at the same price, since the fat replaces not meat but water. Cooked meat is less digestible than raw meat and, however it has been cooked, contains less water (about 100 lb. raw boneless meat = 80 lb. cooked). Joints of meat average about 5 per cent of bone, etc.

In most countries outside monsoon Asia the flesh of either wild or domesticated animals is eaten, whilst in some the production is so great as to allow for vast exports. Formerly exports were limited to live animals or to dead meat to near countries, or to salted, etc., meat, but since about 1880 meat has been stored and transported at low temperatures in increasing quantities. Imported meats are alleged to be just as nourishing as fresh-killed meat. There is certainly, however, a depreciation in flavour. The particular conditions in any given area determine what animals are reared.

**Cattle.**—Cattle can be reared in all temperatures except the very cold. The usual conditions for cattle-rearing are those which produce good long juicy grass, *i.e.* summer rain, whilst a winter free from severe frost is desirable. It has been shown in Denmark,

however, that, for dairy cattle, more cows can be reared per unit area and more milk obtained if mixed crops are grown and the cattle to a great extent stall-fed. If fat cattle are required good grass and oil feed are necessary, the oil being provided by the residue from linseed, cotton seed, etc., after most of the oil has been extracted. Maize, buckwheat and turnips form important cattle feeds, while up to six months old the calves require milk, although the cream is removed before they get it. Cattle can stand any amount of wet.

The chief cattle-rearing countries are India (where, however, the oxen are chiefly used for draught purposes), U.S.A., Russia, Argentina, Brazil, Australia, Uruguay, etc.

The chief area in the U.S.A. is west of the Mississippi and east of the Rockies, whilst the corresponding region in Canada is also important. In the south the snowfall is light, whilst to the north the Chinook winds keep the ground clear. Cattle can thus winter outdoors, the grass is good, and some of it (bunch grass) is converted into hay by the hot summer sun, standing in situ, and so of course is available in the winter. The region, too, has hardly sufficient rain for ordinary crops, and so is hardly likely to give place to them, as has usually been the case with increasing population in grazing areas. (Sixty years ago the chief cattle-rearing states of U.S.A. were on the Atlantic seaboard.) The cattle area of U.S.A., moreover, is very near to the flax, cotton, maize, and grain areas, and residues for fattening are therefore very easily accessible.

In Argentina and Uruguay cattle are reared on the natural grass land of the pampas, but in this case these are probably not permanently located areas and already the more accessible lands have been cropped by corn, etc.

Beef, more than any other kind of meat, is canned in the cooked state. The great centres of the industry are Chicago, Kansas, St. Louis, Omaha, in the U.S.A., whilst Fray Bentos and Paysandu, in Uruguay, and Pelotas in Brazil are equally famous.

Meat contains a certain quantity ( $\frac{1}{2}$  to 1 per cent) of substances soluble in water, called extractives. These extractives are removed by boiling up the chopped meat with a little water, under pressure. The filtered extract is then evaporated. The result is an extract

like Liebig's. In certain cases (like Bovril) from 10–15 per cent of the meat fibre is added to the extract.

These extracts are of little or no value as body-building substances, but they are to a certain extent stimulating to the muscles and very pronouncedly stimulating to the stomach. There is a very large industry involved in their manufacture and sale. They are, of course, usually made where meat is cheap, but there is one large firm which manufactures in London.

**Sheep.**—Sheep require somewhat different conditions from cattle. In particular they cannot endure wet pastures, which cause the foot-rot; on the other hand they thrive on such short grass or even thorny bush (spinifex) as would starve cattle. They are therefore reared typically on downs, in flat pastures on porous soiled country, *e.g.* chalk, and in the mountains.

Sheep are reared in all white population countries, the most important in this respect being the Argentine, Australia, Russia, U.S.A., Turkey (in Asia), the United Kingdom, New Zealand, South Africa, Spain, etc.

Mutton is usually exported frozen, not chilled, or canned, etc., but live sheep are exported from Algeria to France. In some countries sheep are entirely grass-fed, but in other areas the feed is supplemented by clover, rape, turnips, etc. The folding of sheep is regarded as almost paying for itself by the manurial value to the next crop. Sheep are very liable to attack by flies, and they need periodical dipping in some poisonous bath (sheep dip).

The best mutton comes from sheep which have had a salt feed (*du pré salé*), and it is for this reason that some Australian mutton is regarded as of fine quality, since the scrub of Australia is of salty character.

Lamb, or the flesh of young sheep, is as a rule very tender, and is, therefore, much sought after, but it is, like the flesh of most young animals, somewhat lacking in flavour, and for that reason is usually served with a piquant or savoury sauce. It fetches a somewhat higher price than mutton.

**Pigs.**—Pigs are reared in all non-arctic countries except those with a Mohammedan population. Pigs are naturally forest animals and are reared as such in many parts of the world, and especially in oak and beech forests, where they feed on acorns and

beech mast. This kind of breeding continues in Serbia, Russia, etc., but such pigs are small and lean. Pigs are also reared in the great maize-growing districts, *e.g.* Iowa, Illinois, Nebraska, etc., of the U.S.A. ; they consume about half the crop, which is the most valuable monetarily in the world. It is very unfortunate that corn-fed pigs do not produce good bacon, and that is the underlying cause of the strong flavour of the American bacon which to some tastes is unpalatable. The best pigs are reared in dairy farming areas, Denmark, Ireland, etc., where they have for food separated milk and butter-milk supplemented with barley meal. It is from such pigs that the best bacon is obtained.

The U.S.A. is the greatest pig-rearing country in the world, other countries engaged in pig breeding being Germany, Austria, Hungary, Russia, France, and China, all of which have produced pigs for ages. Canada and South Africa are amongst the latest countries to contribute to the European pig market, and the bacon from both countries is very good. Canada also sends a fair quantity of frozen pork to England. At present, however, it is often rather coarse.

Swine's flesh is, of course, usually exported in the form of bacon or ham. This preserved meat is either prepared by a process of salting (common salt, saltpetre, Chile saltpetre and borax and sugar are used) and the product is known as green bacon or else the meat is only partially salted and then smoked. The best bacon is prepared from the smoke of oakwood sawdust. Smoked bacon will keep good longer, and fetch a higher price, than green bacon. Bacon forms a particularly concentrated and valuable food, and the fat in it is present in a very fine granular form very easy of digestion even by bilious subjects.

Some pork is canned (especially at Chicago) and pig fat is melted down to form lard, a very valuable commodity.

Goats are important flesh animals in certain districts, usually rather dry and arid ones, *e.g.* Turkey in Asia, South Africa, and India, but their flesh is not a marketable commodity from the world point of view.

**Horses.**—Horse flesh, although consumed on the Continent of Europe, is not generally a food product. It is stated to be of high food value and cheap. But, of course, it is only cheap on

account of the limited demand, as horses are more expensive to rear than cattle. The chief use for horses is for draught purposes, and they are bred in many countries, forming important elements in trade. The largest numbers of horses are bred in Russia, U.S.A., Argentine, Venezuela, Brazil, New South Wales, Hungary, North Africa, etc., although some horses are bred in all civilized countries. The horse is not very sure-footed, but the product of crossing with the ass is sure-footed, and so this animal is used in mountainous countries, *e.g.* Spain, Mexico, the Andes, etc. Since the size of the cross-breed is determined by the mother and as, of course, strength is a great object, the cross is usually made by a father ass and mother mare and the offspring is a "mule," as large as a horse; when the mother is an ass the resulting "hinny" is small. Special large asses are bred in Spain, etc., for the production of mules.

**(II) MILK AND MILK PRODUCTS.**—Milk is a fluid secreted by female mammals and upon which they feed their young. It is thus obviously a perfect food for the particular infant mammal for which it is designed, and although the milks of different animals vary within limits, yet with modification, such as dilution, the milk of one mammal does fairly well as a substitute for that of another. In consequence, all over the world, the milk of certain mammals is used as a human food. The milk of the cow is much the most generally used, but under varying circumstances the milk of the goat, ewe, mare, ass and camel are also employed.

Dairy cows are specially bred for the purpose and kept within about a 6-7 hour transport distance of the great population centres. They need good grass, which involves a summer rainfall, and since accessibility is important they are usually kept in the plains. They are kept in enclosed areas. Although the foregoing are the usual conditions, yet in Denmark recently more cows per acre and more milk per acre have been maintained and produced by utilizing the land for general fodder crops upon which the cows are fed. When the milk is not to be sold fresh but manufactured or preserved, nearness to a town ceases to be important, yet profitable dairy farming can still be carried on.

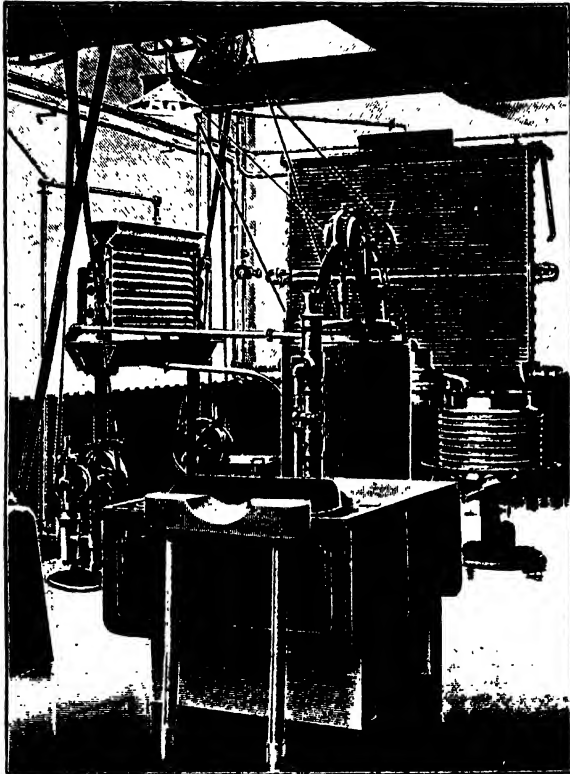
Milk contains all three of the chief forms of food, *e.g.* fat, carbohydrates, and proteins, and it contains in addition from

87-88 per cent of water. A good milk should contain at least 3 per cent protein (chiefly casein), at least  $3\frac{1}{2}$  per cent fat (cream), and at least 4 per cent carbohydrate (lactose or milk sugar). Whilst these are the minima that would be accepted by any analyst of common sense yet the regulations of the Board of Inland Revenue will not consider a milk deficient in fat unless it contains less than  $2\frac{3}{4}$  per cent fat. It is safe to say that in general a milk with  $2\frac{3}{4}$  per cent fat only has been diluted by about 33 per cent added water, and if, for example, milk is sold at 1s. per quart this is really equivalent to 1s. 4d. per quart. The farmers say that cows can give milk of less than  $3\frac{1}{2}$  per cent fat, but this is only true of cows unfit to use which are fed, or starved, on food which is unfit for them. A further difficulty with regard to a proper milk supply in England is that although the initiative of prosecution lies with the local authority, yet the vendor can, if he choose, demand a Government analysis. This is usually put in hand so late that except for inorganic adulteration the result of the analysis is valueless.

In Britain there is no bacteriological standard for milk (although there is in some countries, *e.g.* U.S.A.), and since milk is very easily contaminated and forms a good culture solution for tuberculosis, typhoid, typhus, etc., germs, this is absolutely deplorable. Farmers very rarely indeed wash the udders before milking, and as they are almost invariably caked with dung this constantly falls off into the milk. Further, in order to get the requisite grip on the teats the farmers lubricate their hands in the first of the milk collected and periodically afterwards. The hands are not as a rule washed before milking. The mechanical milkers are, of course, an improvement from the point of view of cleanliness, but unfortunately those as yet on the market do not extract the last of the milk, and as, unless a cow is milked dry she soon ceases to give milk, all mechanically-milked cows have to be finished by hand.

Milk can be decomposed in two chief ways, *i.e.* either by the bacteria of the stomach (rennet) when junket or curds and whey are produced, or else by the lactic acid bacterium when lactic acid is formed. In this latter case the milk is said to be sour, and it happens by means of bacteria in the milk itself, in from one day onwards according to the atmospheric conditions. The hotter.

and more thundery the weather the more quickly is the lactic acid produced. This lactic acid fermentation can be arrested by the addition of certain germ poisons, some of which are allowed by law and others of which are not. The most usual illicit preservative is



DAIRY PLANT

Showing milk-receiving tank, milk pump, regenerative heater, pasteurizer, separator, cream cooler and large milk cooler in two sections, one for water and the other for brine cooling

formaldehyde, which is poisonous to humans, and the most used legal preservatives are boric or boracic acid and hydrogen peroxide, which are also slightly poisonous to humans. Such adulteration is certainly harmful where the diet consists chiefly of milk, as in infants, typhoid patients, etc. Boric acid does not preserve milk for long. Milk once rendered sterile will remain so practically indefinitely if no fresh germs are admitted, *e.g.* if sealed in tins or



bottles, and since milk can be sterilized by bringing to temperatures above boiling, under pressure, this is done and the milk sealed up. Such milk is absolutely sterile, but has a pronounced flavour objectionable to some people, and owing to alteration in the protein it is much more difficult of digestion.

Since milk contains 87-88 per cent of water it could be greatly reduced in bulk without removing anything of food value, and such condensed milks are now very common. They are very important, since they enable milk produced in Switzerland, U.S.A., or Australia to supplement home supplies. The fat is often first separated and sterilized and the separated milk evaporated down. The cream is then either returned to the milk with, sometimes, sugar (full cream milk) and tinned, or the cream and condensed separated milk are tinned separately.

The ingredients of milk which have food value can be obtained in the solid form if the water be very rapidly removed, *e.g.* by finely spraying the milk into hot air, and this operation is carried out on a large scale in Cheshire, New Zealand, U.S.A., etc. Such dried milks keep good for a long time, even in a non-airtight tin, but gradually acquire an unpleasant flavour and become less soluble. Sealed up they keep for years. Certain infant foods, *e.g.* Glaxo, consist chiefly of dried milk.

No kind of preserved milk is satisfactory in the manufacture of margarine, for which absolutely fresh milk is required in much increased quantity in recent years.

Goats' milk is somewhat richer in fat than cows' milk, and is especially valuable in that it does not contain the germs of tuberculosis, and also that goats can live in regions which would offer no feed to a cow.

Mares' milk is chiefly known to the western world from its fermented product "koumiss." It can be alcoholically fermented at the same time as it is soured, and as the constant agitation in the course of its preparation renders the protein (casein) easily digestible, and even partly predigested, it is a very valuable food in tuberculosis and other wasting diseases where tissue requires rapid replacement. By means of koumiss very much more nourishment can be taken than by an ordinary milk diet. "Kephir" is an imitation of koumiss made from cows' milk. It seems almost equally good.

**Cheese.**—When milk, either with or without its fat, is acted upon by “rennet,” or an acid like vinegar, under certain conditions, the protein clots to a “cheese.”

Rennet is obtained by soaking the stomach of a milk-fed calf in brine. The brine dissolves out the rennet, which is preserved by the addition of alcohol.

In making a good cheese, *i.e.* one containing the cream of the milk, the rennet is mixed with the milk at about 28° C. or 82° F. The milk turns into a junket-like substance. This is cut about to ensure the settling of the curd and the separation of a fluid, the “whey.” The temperature of the milk may be increased 3 or 4° C. in the process. When the operation is properly carried out the curd contains all the cream. The whey is removed and the curd left to “ripen,” after which, if a “hard” cheese, *e.g.* cheddar, is desired, the curd is pressed, but for a soft cheese, *e.g.* gorgonzola, it is just put in a cloth.

Most English cheeses contain full cream—Stilton, indeed, has additional cream—but some Dutch cheeses, for instance, are made from skim milk.

Ewes’ milk is used in the preparation of true Roquefort, whilst Parmesan is made from half cream goats’ milk. Cheese is made in all milk-producing countries. Canada and New Zealand export very large quantities to the United Kingdom. Cheese is a very concentrated food and with bread (to provide carbohydrates) is a very valuable food.

**(III) POULTRY AND EGGS.**—Poultry—fowls, ducks, geese, turkeys, and guinea fowls—are most favourably reared in conjunction with a grain industry, where they consume the offals and, of course, grain which shakes out of the ears of the standing or cut corn. Maize is a particularly fattening grain to use. Poultry are, of course, also reared in pens on a large scale, but even then they are most profitably kept in a grain region.

Fowls do well under almost all conditions and ducks also, although water is desirable for the latter. Geese should have a grass run; turkeys are very delicate in their early stages and must be kept from damp, whilst galeenies require trees.

Turkeys are chiefly reared in U.S.A., Canada, Italy, France, Ireland and England; geese in all northern countries, as well as

special breeds in hotter regions ; whilst ducks and fowls are bred almost everywhere—in tropical Africa, China, Japan, India, North and South America, Russia, and all European countries. Poultry are cold-stored and exported.

Eggs are a commodity in enormous demand all over the world, and there is at present a great shortage of them in Western Europe. The deficiency is to a certain extent made up by imports of cold-stored, sodium silicated, or waxed eggs from U.S.A., Egypt, Morocco, and China. Siberia and Russia, which formerly supplied large quantities, will probably do so again in the future, although Central Europe will certainly take increasing proportions of the output.

Another way to relieve the scarcity is by the breeding of special fowls for egg-laying purposes. This has been extensively done in England, and very large increases in the yield per hen have been recorded. An additional advantage of some of these improved breeds of fowl is that they produce a far larger proportion of eggs in the cold months than is usual.

An even supply of eggs is also maintained by drying them at low temperatures or *in vacuo*. Sugar is sometimes added to these preparations. The liquid eggs used during the war period appear to have been wild fowls' eggs cold-stored and bottled in England.

Egg and custard powders contain no egg or egg-like substance, but merely starch, sometimes baking powder, and a dye. The food value of eggs is over-rated. They contain no carbohydrates and are equal to rather less than their weight of good meat. When raw or lightly cooked they are, however, very easily assimilated.

**RABBITS.**—Rabbits form a fairly important item in certain areas (chiefly rural). They are bred tame in Belgium and some other places, but the great bulk of those on the market are wild. They do considerable damage to crops and farmers say forty rabbits eat as much as one sheep. The sheep is almost certain to get to the market, and, in addition, of course the wool is very valuable ; there are not many farmers, therefore, who would willingly keep rabbits. In Australia, where they were introduced from England and where there are none of their natural enemies to keep them in check, they are a real plague and menace. They are, unfortunately,

from their quick breeding, very difficult to eliminate, and their burrowing habit makes it very difficult to exclude them from desired territory. Subterranean wire fencing has to be resorted to. Australian rabbits are tinned or frozen for export. Hares, deer, pheasants, partridges, etc., all form rather unimportant foodstuffs, although it is of interest to note that up till quite recently very large quantities of Manchurian game birds would find their way to the United Kingdom.

The only important insect food supply in Europe is honey, although various peoples eat locusts, grubs, etc. Honey is best obtained from bees with clover and heather near at hand. Latterly bees have suffered much from the Isle of Wight disease, but immune crosses have been bred. Unfortunately some of these cross-breeds are as fierce as hornets and not suitable for domestication. Given healthy bees, however, bee-keeping is very profitable and likely to increase in the future. New Zealand and Jamaica export honey to England.

The honey, which is digested nectar from flowers, is excreted from the mouth of the bee into waxen moulds. The wax is also manufactured by the bees and secreted about the body. Bees-wax is an important commodity, although there are now many substitutes. It can be bleached white by oxidizing agents, *e.g.* nitric or chromic acids, or by sunlight.

Bees are of great value to agriculture, as in their searchings for nectar and pollen they fertilize the ovaries of plants and so ensure fruitfulness.

There is one reptilian source of food, *e.g.* the green turtle. The soup is made from the shield or "shell." The softer parts of the shell, after boiling, form the celebrated green fat.

## CHAPTER XVII

### STIMULATING, NON-ALCOHOLIC BEVERAGES

THOSE in most common use are tea, coffee, cocoa, and maté, although there are a great many substitutes for them. The one most widely produced and used is tea.

**TEA.**—The tea plants are shrubs, *thea chinensis* and *thea sinensis*, and various hybrids. Their place of origin is not known, some authorities believing that the plant was indigenous to India, whence it was taken to China, and subsequently re-grown in India, others believe it to be of Chinese extraction, whilst others again believe that it was native to the border territories of China and Burma. Tea is produced chiefly in China, India (Assam and Ceylon), Japan, Java, Natal, etc. The cultivated plant is grown from seed, and kept pruned to a low shrub. It thrives best on well drained slopes with a heavy rainfall and no frost. The plant comes to full bearing in the third year, when, in the hotter regions, harvests can be gathered. The young leaves are picked by hand and kept graded in the picking: thus the extreme uncurled terminal leaves are kept for flowery Pekoe, the next leaves being orange Pekoe, older ones being Pekoe, Souchong, and Congou in order. This is the correct nomenclature, but in commerce these names are apt to be given to different grades of tea. In particular Congou is the name sometimes applied to blended teas. Although in general it can be stated that the smallest leaves produce the best tea, yet the finest tea the author ever tasted (a sample of that grown for the last Emperor of China) had leaves which, when unrolled, were from 2 to 3 in. long.

The hand-picked and graded tea leaves are allowed to wither naturally, if black tea is being prepared, but if green tea be required the withering is done at a higher temperature (about 72° C.), thus preventing subsequent fermentation. The leaves are then rolled, and in the case of black tea fermentation sets in. Since black tea contains less soluble tannic acid than green tea, and also contains more essential "tea"-ness, it must be presumed that fermentation converts some of the tannic acid into insoluble substances and at

the same time liberates essential oils from their compounds. As soon as the fermenting tea acquires a certain odour it is heated in sieves when it turns black and is ready for use.

Tea is usually marketed in metal (lead) lined cases of some non-resinous non-essential oily wood (teak and bass wood are both suitable), otherwise the tea would quickly take up a foreign flavour. The chief consumers of tea are the countries of origin, Thibet and the adjacent countries, the United Kingdom, the British Colonies, and the U.S.A.

Tea owes its value as a drink to an alkaloid (caffeine or theine) and the essential oils which it contains. Caffeine, or theine, is well known, can be isolated and synthesized, and is administered as a drug, but the essential oils have escaped detection. Both of these constituents seem to be nervous and cardiac stimulants. Indian teas contain more caffeine than China teas as well as more soluble tannic acid, but China teas as well as Japanese teas (not exported to England) have a more delicate flavour. Indian teas are rarely prepared green, but China teas are often, and Japanese teas usually, so prepared.

The best Indian teas come from Darjeeling, and the best China teas are grown south of the Yangtse and exported from Hankow and Foochow.

There is no absolute objective standard for tea, and its quality has ultimately to depend upon the taste of a rather weak brew of the tea by "tea-tasters." These judge not only by the taste but by the appearance of the spent leaves.

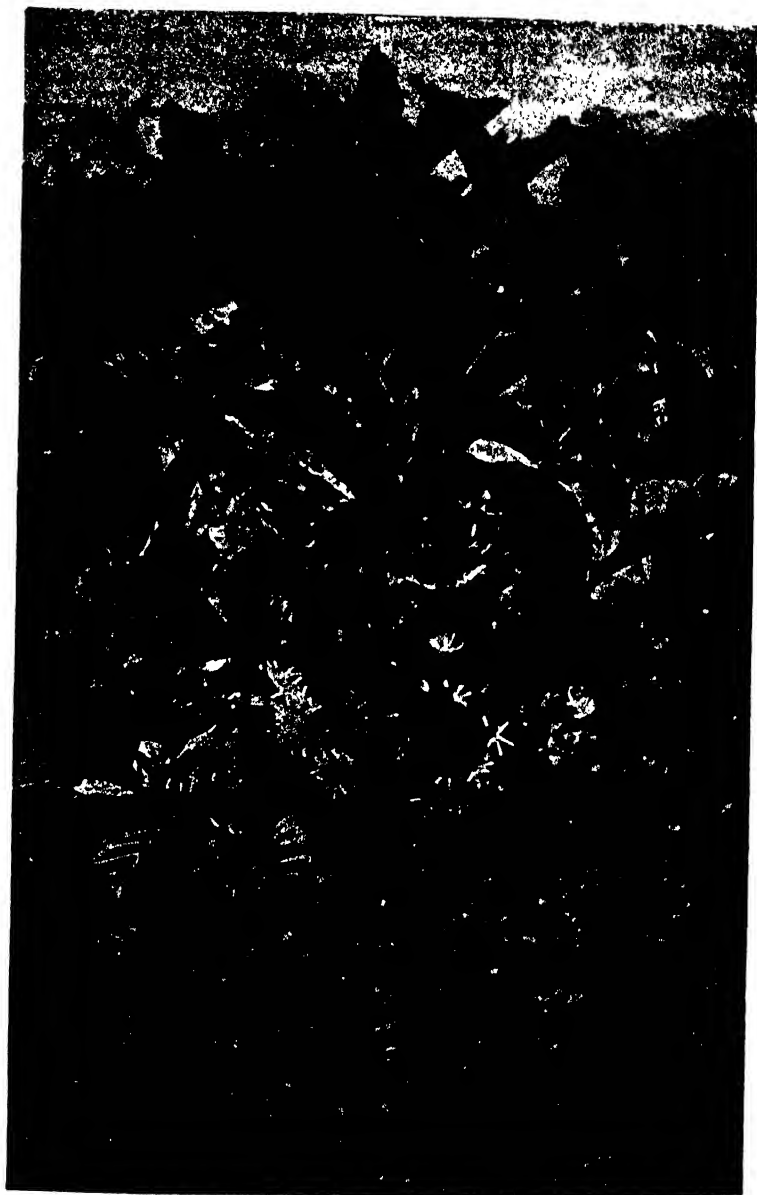
Practically all the caffeine and essential oils are removed from tea by a reasonable quantity of nearly boiling water in two or three minutes, and therefore there is no real point in the addition of hot water to the leaves to make a second brew. The resulting infusion is not "tea" at all, but contains a good deal of bitter substances. To avoid the presence of these in the first infusion it should be drawn off into a separate pot after standing about five minutes. The water originally used should be oxygenated, *i.e.* it should not have boiled for a long time, whereby all the dissolved air would be driven out, but should be used immediately it boils. Tea so prepared is probably quite harmless and only beneficial.

Tea has been used in Asia for a very long time but has been

introduced into England since 1600. In 1660 Pepys wrote: "I sent for a cup of tee, a China drink, of which I had never drank before."

**COFFEE.**—Coffee has had a similar history to tea in that it has been used for many centuries in its native country, and its use in Western Europe began about 1650. After its introduction into England it speedily became very fashionable, and "coffee houses" were established only to come under the ban of Charles II, who thought the frequenting of them to be of too revolutionary a character. Coffee was probably indigenous to Abyssinia, but the trees were subsequently cultivated in Asia Minor and Arabia, whence the best varieties still come (Mocha). It was transported to Java, India, Ceylon, and to the New World, and good varieties are largely grown in Central America and northern South America. Over 70 per cent of the world's production, however, comes from Brazil in the country to the north and west of Rio de Janeiro. This coffee is, however, of inferior quality and is blended with small quantities of finer varieties for retail sale. The coffee tree is a small tree (up to 20 ft. high, but pruned to less than 10 ft.), tropical, but not equatorial, and best grown at an elevation (2,000 ft. or more) above sea level. At one time there were important plantations in Ceylon, but blight and disease made the harvest very uncertain, and the coffee trees have now largely given way to rubber. The young plants are planted out in their proper stations when about six months old and are in full bearing in the third year. The plant has red berries something like cherries, and these are hand-picked. Embedded in the pulp are two seeds (coffee berries). The pulp is removed mechanically and the berries washed. They are then allowed to ferment somewhat and sun-dried. The seeds are usually marketed at this stage. They are enclosed in a transparent skin (parchment coffee) and this is broken and removed by very light rolling by the wholesaler, who then delivers the seeds to the shops. In the shops the berries are roasted in revolving perforated cylinders, and sold for immediate consumption, either ground or unground. The roasting of the coffee generates the oil (cafféol) which gives the coffee its characteristic smell, whilst water and perhaps a little of the caffeine are lost.

Coffee is, in England, often sold diluted with the roasted ground



A LIBERIAN COFFEE PLANT IN FLOWER



root of the endive (chicory), the chief effect of which is so to colour the infusion as to make it appear that more coffee has been used in preparing the infusion than is actually the case. At the present time chicory is as dear as coffee and it is not in use.

Coffee is best made by a recurring stream of hot (not quite boiling) water, which percolates through the ground seeds to a heated reservoir whence it is returned over the coffee again. Compared with tea it is a very expensive drink, as a pound of seeds will only make a gallon of good infusion. For this reason, probably, it is not very popular in an empire like Britain, which provides large quantities of the much cheaper tea. The finest coffee is Mocha, which, although originally from Arabia, is now grown in Guatemala and elsewhere in Central America. Mysore coffee is another good variety from Ceylon and Java. Retail coffees are nearly all blends.

Apart from its taste, coffee is used for its stimulating and sustaining powers. Like tea, its chief action is due to caffeine and essential oils. A given weight of coffee contains not more than a quarter the caffeine that would be present in the same weight of tea, and this is perhaps an additional reason why more coffee than tea is used in preparing a brew.

**MATÉ.**—Maté is another drink which contains caffeine and is therefore stimulating. The drink is prepared from the dried leaf of a holly tree (*ilex paraguayensis*), which is cultivated in Paraguay and the neighbouring countries, and is often called Paraguayan tea, and besides a large local consumption a very considerable amount is exported through Brazil. As in tea, the young leaf shoots produce the best infusion. They are dried and roasted. The infusion is usually sugared and flavoured with lemon juice.

Maté is said to be more sustaining than tea or coffee, and since it contains less soluble tannin it must almost certainly be quicker of digestion than tea, especially in conjunction with a gelatinous, *e.g.* meat, food.

**COCOA.**—Cocoa is the name for the prepared drink only, the tree being known as cacao. The cacao tree (*theobroma cacao*) is indigenous to equatorial South America, and was discovered there by the Spaniards, who found the natives fully acquainted with the method of preparing a drink from it. It was probably introduced to Europe by Columbus himself.

The tree requires equatorial conditions, as regards both high temperature and high rainfall, and it is grown on the plains as it likes very moist soil. Left naturally the plant grows to about 20 ft. high, but when cultivated it is pruned so as to make harvesting easy. Being of tender-stemmed, low-growing forestal origin, they need protection under plantation conditions from both wind and sun, and stronger, taller trees are intergrown, *e.g.* coral bean. The plant comes into bearing after four or five years and then fruits all the year round for about thirty years, but the chief harvesting takes place twice a year. The fruit is gourd-like, similar to a cucumber, and similarly again many seeds are embedded in the pulp. After the seeds are removed from the pulp they are packed in barrels and allowed to ferment, whereby a bitter taste is lost and new and desirable flavours engendered as in tea and coffee. They are then left in the air, but protected from the weather, to dry. This is the usual condition of export. The further manufacture of cocoa consists in roasting, rolling, and winnowing, by which means cocoa nibs are prepared. If these nibs are required for the preparation of chocolate their fat is not removed, but if cocoa for drinking is required they are warmed and the fat expressed. This fat (cocoa-butter) is largely used medicinally for suppositories, etc., since it melts at the temperature of the human body. The cocoa is then cast into slabs which are finely ground.

Unlike tea, coffee and maté, a clear solution of the soluble ingredients of cocoa is not required, but instead the whole of the manufactured preparation is consumed intimately mixed with water. This is probably demanded by the fact that theobromine, which is the stimulating drug in cocoa corresponding to caffeine, is only with difficulty soluble in water, whereas caffeine is very soluble. In addition the fat is nutritious. Now cocoa is practically insoluble in water, and therefore various devices have been adopted in order to secure a homogeneous emulsion. One of these in high favour with certain manufacturers consists in diluting the cocoa with about its own weight of starch (which is cheap). When boiling water is added to such a preparation the starch forms a weak paste which holds the cocoa in suspension. Very finely milled cocoa is sometimes heated in order to render it more easily miscible with water. The Dutch manufacturers take advantage

of the fact that theobromine, as well as some of the tannin of cocoa, is soluble in alkali and so they add a small amount of some alkali to their preparations. This practice has been objected to, but more from prejudice than any proven ill effects. Cocoa is usually regarded as more of a food than tea or coffee. It certainly contains some fat, but it is very doubtful if its nitrogenous bodies are real foods. They do not seem to be assimilated at all. Chocolate is cocoa with its natural fat melted up with sugar and usually a flavouring (vanilla).

The chief centres of production of the cacao plant are Ecuador, Venezuela, West Indies, Trinidad, Brazil, the Gold Coast, and adjacent islands such as San Thome. Cocoa contains practically no caffeine, but this drug is in one case added in the form of the kola nut, which contains it.

(Whereas in this case a stimulating principle is added, preparations of coffee are sold from which the caffeine is extracted, whilst harmless but not very stimulating substitutes for coffee, *e.g.* ground roasted barley, are also sold.)

## CHAPTER XVIII

### FERMENTED DRINKS AND ALCOHOL

**FERMENTED DRINKS.**—Some of the most primitive men of to-day produce alcoholic drinks by the fermentation of various plant juices ; and the practice has undoubtedly been in force from the very earliest times. Alcoholic fermentation is carried on to-day in all countries of the world except those too cold for vegetation. The United States has prohibited the sale of alcoholic drinks, but that will not necessarily prevent their production and consumption. Some countries derive large revenues from duties on various fermented beverages.

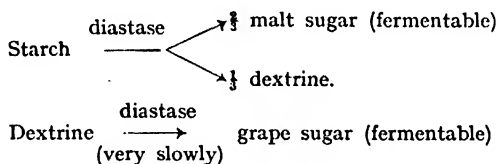
There are hundreds of substances known to chemists as alcohols, but the only one which enters at all largely into the composition of stimulants is ethyl alcohol ( $C_2H_5OH$ ) or simply alcohol. It is obtained wherever a yeast decomposes a sugar which may be present in the plant, as such, or may result from the easy hydrolysis of a starch. Since nearly all plants contain starch or sugar, and most contain a yeast, it will be seen that the production of at least crude fermented drinks is a very simple matter.

Alcoholic drinks are divided roughly into three main groups—

- (a) Those formed directly by fermenting grain, and called beers ;
- (b) Those formed by fermenting the juice of the grape and to a slight extent the juices of other fruits and vegetables. These are called wines ; and
- (c) Those obtained by the distillation of either beers or wines with the object of increasing their alcoholic content. This is the class known as spirits.

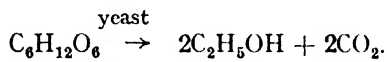
**Beer.**—The grain usually used in Western Europe and America for the production of beer is barley, which is often specially grown for this purpose, *e.g.* in the Trent Basin and other light soil areas. The barley used is always of the two-rowed sort. The first stage is the production of malt. For this purpose the grain is prepared by heating in mass to about  $105^{\circ}F.$ , and then machine sorted to remove impurities. The cleaned grain is then steeped in water, preferably a hard water containing calcium sulphate and bicarbonate

such as the Trent water at Burton. The seeds of course swell and absorb water. When the desired state is reached the steeped grain is drained and left to sprout, and since the conditions are very favourable to the growth of moulds the mass is treated with a weak solution of calcium bisulphite to kill them. With the sprouting of the barley certain "enzymes," especially diastase, are produced, and in addition the starch is rendered liable to easy attack by the enzyme. An enzyme is roughly a lifeless substance with most of the chemical properties of bacteria. They are often the products of bacteria, and it is probable that many of the effects of bacteria are really due to their excretion products, *e.g.* tetanus or lockjaw is specifically poisoning by the excretion product of the tetanus bacillus. Diastase itself is able to convert starches into sugars, and a limited quantity of diastase seems able to do an unlimited quantity of work. The "green malt," as the sprouted barley is called, must not develop too far, and at the appropriate stage (about twelve days) is killed by heating and air drying for about three days at temperatures finally reaching nearly  $70^{\circ}\text{C}$ . It should be noticed that at such a temperature the living things are killed, but the diastase is unaffected, although, of course, no more is produced. The temperature is now raised somewhat higher to a point fixed by the kind of beer required. For pale beers and ales lower temperatures are required, but for stout, etc., the malt is heated until some of the sugar first produced is converted into caramel and the malt goes black. At this higher temperature, too, the diastase is destroyed and so no more sugar is produced. The sugars now present in the malt are as follows—



The malt is now ground up and mixed with water to form a mash. Hard water, such as that of Burton or Dublin, is required, and if not immediately available is artificially produced by the addition of the required salt; this preparation of the water is called Burtonizing. The mash is warmed and then boiled up for

about two hours with hops, whereby all further diastase and bacterial action is stopped and a bitter flavour is acquired, due to the extraction of various substances from the hops, *e.g.* tannic acid. The wort is then cooled and ready for the yeast. The yeast should be most carefully selected, as otherwise quickly souring beers may result due to the presence of acid-forming ferments. The yeast grows in the wort, and as it grows converts sugar into alcohol and carbon dioxide—



The large square vat in which the operation is carried out is heated by means of copper steam pipes to a varying temperature according to the kind of beer required. Lager beers are, indeed, not heated at all but cooled. On the other hand, strong beers are brewed at a fairly high temperature, but not, of course, sufficiently high to kill the yeast. The beer is periodically skimmed, and the course of the reaction watched by means of testing the density of the solution which steadily diminishes as sugar is converted into alcohol. When the brew is judged complete it is drawn off into casks, left for further fermentation, and then fined with gelatine and sulphur dioxide. A white spume exudes at the bung and then the beer is ready for sale.

Barley is, of course, not the only substance which can be used for beer-making, and maize, potato, etc., have all been used.

There are many different kinds of yeast and the variety used greatly affects the flavour of the resultant beer. Much research is now carried on with the idea of obtaining the best kinds of yeast.

**Wines.**—Wines have been made domestically since the earliest times and commercially for thousands of years. Domestic wines are made from various fruits, elderberry, black currant, banana, etc., as well as from such things as rhubarb, parsnip, cowslips, and palm sap, but commercial wines are made from grapes. The chief countries producing wines are France, Italy, Spain, Austria, Hungary, Germany (the Rhine Valley), South Australia, Argentine, Algeria, and California.

The vines, which are always grafted on to a wild stock, are arranged in alleys and kept to such height that they can easily be picked.

When the grapes are ripe the bunches are hand-picked and the juice pressed out by machine presses. The juice is then removed and left to ferment by the yeast, which is in the "bloom" on the grapes. (In some red wines some of the skins, etc., are left in the juice.) As the fermentation proceeds carbon dioxide gas is evolved and a precipitate called lees, consisting amongst other things of potassium hydrogen tartrate (argol), settles out at the bottom. Argol is the commercial source of cream of tartar, tartaric acid, and Rochelle salt. After from three weeks to a month the fermented juice is drawn off into casks and fermented still further for some months when it is fined with isinglass (gelatine) and either bottled or barrelled according to requirements. It is at these stages that the treatment which confers particular characteristic flavour or "bouquet" is given. Thus sparkling wines are bottled before fermentation is over so that gas is produced in the bottle (up to about 6 atmospheres pressure); some ports are kept in barrels, others bottled early, etc. In the barrel wine undergoes complex changes, one of which is that the water soaks through the wood of the cask much quicker than does the alcohol and then evaporates. By consequence the wine gets "stronger."

After bottling, except in the case of sparkling wines, no more alcohol is produced, but certain other changes go on due, probably, to micro-organisms other than yeast, and the bodies produced, though in minute quantities, have a good deal to do with the final taste of the wine. One of the chief of these bodies is oenanthilic aldehyde, and this is to a certain extent artificially added to wines and to brandy.

Wines cannot be produced, by fermentation, of a greater alcoholic strength than 14 per cent, since solutions of alcohol of greater concentration poison the yeast, but many people prefer a wine of greater strength than this, and so the wines are "fortified" by the addition of brandy or absolute alcohol. Port, Lisbon wine, sherry, Madeira, and some champagnes, *e.g.* for the British market, are so fortified, whilst hocks, clarets, and burgundies are natural wines. When all the sugar in the grape is fermented the wine is said to be dry. Hock and good champagne are dry wines.

One of the chief difficulties in connection with the storage of wine is in connection with the stopper for the bottles. No better

substance than the bark of the cork oak (Portugal) has been found, but unfortunately this is liable to rot and also to give bad flavour (uskiness) to the wine. To prevent this a small quantity of sulphur is added to wines, but even then wines which are kept a long time in bottle must be recorked after some years. There is a considerable loss in champagne due to the fact that this wine, and all other sparkling wines, cannot be recorked. Consequently when the cork goes the wine is practically worthless.

In Japan a wine or beer is fermented from rice and called "sake." It is pale yellow in colour and served warm. It has a very fine flavour indeed, and will almost certainly be in demand in Europe if people ever get to know what it is like.

**SPIRITS.**—Spirits are solutions of alcohol of greater strength than can be obtained by fermentation and are obtained by distillation. The chief commercial spirits are alcohol itself, gin, methylated spirit, whisky, which can be regarded as a distilled beer, brandy, which is a distilled wine, and rum.

**Whisky.**—The early stages in the preparation are similar to those for ale, *i.e.* a wort is made from a pale barley malt. The fermented liquid is then distilled. This should be done in a pot still, *i.e.* a still very much like an ordinary retort with few if any fractionations. The first and last fractions are rejected and redistilled, the middle fraction being whisky. In a pot still so few fractionations go on that the resultant distillate tastes of the substance from which it is produced, but in a patent or Coffey still so many distillations are carried on at one time by making the ascending vapours redistil previous condensations that an almost pure alcohol results without much flavour except a rather unpleasant one. By consequence the distillate is called silent spirit. Generally speaking pot still whisky is mixed with patent still whisky for sale. Raw whisky has a rather unpleasant taste, but this is removed by storing in a sherry cask for not less than three years, the longer the better. After whisky is bottled it does not undergo any further change. Whisky can be prepared from maize, rye, and potato, as well as from malt, but such whisky is of doubtful virtue because it is very apt to contain more of a harmful impurity, amyl alcohol, than does malt whisky.

The higher fractions of whisky, "fusel oil," consist principally



of amyl alcohol and are fractionated to obtain this substance moderately pure. Amyl alcohol is of great commercial importance in the manufacture of various amylates which are used in the preparation of aeroplane dope, celluloid, and flavourings.

Whisky as well as brandy may not be retailed in the United Kingdom at a strength higher than 30° under proof (30° U.P.). This very clumsy method of standardizing the sale of spirits depends upon the fact that whereas alcohol burns, water does not. If gunpowder be moistened by a strong solution of alcohol and a light applied the alcohol will burn and ignite the gunpowder. But at a certain dilution, whilst the alcohol will still burn, the gunpowder becomes so wetted with water that it will just not ignite. That strength of aqueous solution of alcohol is called "proof spirit," and to it all other solutions are compared. Thirty under proof means that 70 pints of proof spirit contain as much alcohol as 100 pints of 30 under proof spirit, and 30 over proof (30° O.P.) means that 130 pints of proof spirit contain as much alcohol as 100 pints of 30 over proof spirit.

Proof spirit is 49·24 per cent alcohol by weight, and perhaps in the future all alcoholic strengths may be given as percentages by weight. Volume relations are not at all simple, since there is a contraction when alcohol and water are mixed.

**Brandy.**—Pure brandy is made by the distillation of good wine and the ageing of the distillate in wood, but actually it is made in other ways as well. For instance, the mass, "marck," left after the juice is expressed from grapes is distilled and the result called brandy, and silent spirit is doctored with flavouring into a mixture also sold as brandy. Since the value of brandy, above all other alcoholic drinks, is due to the esters and aldehydes in the wine distillate, and these substances are not present in the imitations, the law should insist that the name "brandy" should be applied only to the genuine article.

The chief brandy-producing region of the world is in the Lower Charente basin (Cognac), but brandy is also produced in Spain (Jerey) and elsewhere.

**Rum.**—Rum is prepared by fermenting treacle or, better, sugar cane sap, and then distilling the product. It is chiefly made in the West Indies. The distillate is coloured brown by the addition of

burnt sugar. Rum contains a large number of volatile esters and is sometimes made artificially from "silent spirit," and some of these esters, *e.g.* ethyl butyrate. Rum is sometimes flavoured with fresh pineapple.

**Gin.**—Gin is distilled from malted grain somewhat similarly to whisky and then flavoured with oil of juniper. Some gin is sweetened with sugar; this is called Old Tom. Gin is made principally in Holland (Schiedam) and London.

**ALCOHOL.**—Alcohol itself is prepared by the patent still distillation of fermented damaged grain or potato. It is a colourless limpid liquid lighter than water and boiling at about 78° C.

Alcoholic drinks have important physiological effects, and although the various esters in the different drinks are responsible for the varying effects, yet the effect common to them all is due to alcohol.

Alcohol has a paralyzing effect on the nerve centres, but it is a very great aid to digestion. It is capable of passing through the stomach wall direct into the blood, and will do so if there is no layer of intervening undigested food. This explains why intoxication is much more easily produced "on an empty stomach." Alcohol produces dilation of the surface blood vessels and consequently a greater flow of blood through the peripheral arteries; a state of warmth is experienced, but actually heat is being lost, so that alcohol should never be taken before exposure to cold. On the other hand, however, it is of great use in restoring circulation after exposure.

Alcohol is used industrially as a solvent for most organic substances, in the preparation of tinctures, drugs and esters, in the dye industry, in polishes, etc. Alcohol can also be used as a motor spirit.

**METHYLATED SPIRIT.**—The very heavy duty on alcohol has made some cheaper substance of like properties a necessity, and rectified spirit (90 per cent alcohol, 10 per cent water) has added to it about 10 per cent of alcohol distilled from wood, mainly methyl alcohol and under 1 per cent (about .4 per cent) of mineral oil or bone oil. Such a mixture has an unpleasant taste but can be used for most of the domestic and industrial purposes for which alcohol is required, *e.g.* for burning and as a solvent. It is known

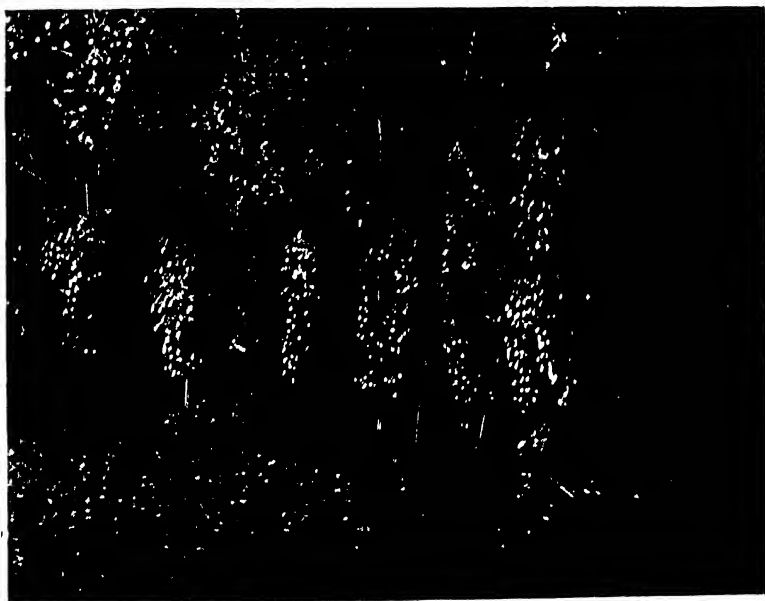
as methylated spirit and gives a cloudiness with water which alcohol does not, and pays no duty. It is possible to get a duty-free mixture which contains no ingredient insoluble in water, for industrial purposes, by arrangement with the customs authorities. Absolute alcohol (over 98 per cent alcohol) can be obtained, duty free, by certain laboratories under very carefully regulated conditions. It should be possible to do so for all purposes other than drinking, scent-making, etc.

Methyl alcohol obtained by the distillation of wood (*q.v.*) is used in the preparation of formaldehyde (formalin) in the preparation of many dyes, for denaturing alcohol (*v.s.*) in varnishes, etc.

## CHAPTER XIX

### SPICES AND CONDIMENTS

**SPICES, CONDIMENTS AND FLAVOURING.**—Spices have been in demand from very early times, and were used in embalming and incense as well as for flavouring. In the Middle Ages spices were hardly less thought of than gold and they formed one of the most



PEPPER VINES

powerful incentives to international trade. The spice most sought after was pepper, and it is very difficult at the present day to realize the enormous importance of this substance in mediaeval times. One of the reasons why spices were in such demand was undoubtedly the poorness of the cooking.

**Pepper.**—Pepper is obtained from the fruit of a vine or shrub (*piper nigrum*) grown in sub-tropical and tropical areas, and especially in Singapore, the East and West Indies. Both black and white peppers are obtained from the same shrub, the kind of pepper obtained

depending on the treatment of the berry. If white pepper is desired the berries are not picked until they are dead ripe. After picking they are depulped and then dried, but for black pepper the berries are picked when just reddening and sun or fire dried with the pulp on them. The pepper is usually ground just before sale.

*Red, or Cayenne, pepper* is obtained from capsicums, a plant of a different genus entirely from the piperaceae. It is chiefly grown in Central America and the near-by parts of North and South America.

Pimento, Allspice or Jamaica pepper is grown in Jamaica (*pimento officinalis*). Before the fruits are ripe the branches bearing them are broken off and the berries sun dried. Allspice is cheaper than pepper and much used.

✓ **Mustard.**—Mustard is nowadays of more commercial importance than pepper, and the plants of which it is the seed are grown on a very large scale. There are two chief kinds, *sinapis alba* or white mustard, and *sinapis nigra* or black mustard. It is the seed leaves of *sinapis alba* which are eaten as mustard in “mustard” and “cress.” The seeds of the mustard plants are very finely ground and sifted, usually twice, into mustard flour and dressings. From the dressings an oil of a type similar to olive oil is obtained which is used for burning in India and also in the manufacture of soap. The fine mustard flour is usually diluted with ordinary wheaten flour and dyed yellow with turmeric.

From black mustard or, better still, from a mixture of black and white mustard seeds a pungent, highly irritant oil “allyl isothiocyanate,” or mustard oil, can be obtained. It is this oil which is the cause of the efficacy of a mustard plaster.

**Nutmeg.**—Nutmegs are the stones or seeds of a small tree (*myristica fragrans*) which is probably indigenous to the Molucca Islands, but which is now grown in many parts of the tropics in the Old and New Worlds. The seeds are surrounded by a scarlet tracery (airils) and embedded in a pulpy fruit. The scarlet surround is removed from the stones, bleached, and put on the market as “mace.” The whitish appearance on the surface of the nutmegs is due to the addition of lime. Nutmegs are sometimes ground before sale, but are better ground only immediately before use.

Nutmegs contain an oil, "mace oil," which is used as a flavouring and also as a "carminative" in medicine.

**Cloves.**—Cloves are the unopened flower buds of a shrub also a native of the Moluccas, and called variously either *eugenia caryophyllata* or *caryophyllus aromaticus*. When the Portuguese took possession of the East Indies as a result of their discovery of the Cape route to India and the East they, following the trading custom of the times, created an absolute trading monopoly with these islands and were particularly careful as regards cloves. The Dutch, who succeeded them, went still further and restricted the trade to one part only of the Moluccas, *e.g.* Amboyna, systematically destroying the shrubs throughout the rest of the group. About 1770, however, the French succeeded in introducing the plant to some of their African possessions, Mauritius, etc. From there it was taken to Zanzibar, which is a great centre of production at the present time, and also to the West Indies. The flower buds, just before opening, are either hand picked (Zanzibar) or beaten off the plants and then dried.

*Oil of cloves*, obtained by the distillation of cloves with steam, is used as a flavouring, as a carminative in medicine, and to reduce pain in dentistry. It is also used in the manufacture of artificial vanilla.

**Ginger.**—Ginger is the rhizome or underground stem of a plant (*zingiber officinale*) native to the East Indies but grown also in China, Indo-China, and the West Indies. Rhizomes, or underground stems, differ from roots in that the latter remain white when exposed to light, whereas rhizomes, which contain chlorophyll, go green, like leaves and above surface stems, under the action of light. Potatoes form a common example of such greening, and of course they are not roots.

The rhizomes of ginger are picked and sometimes peeled (uncoated ginger) whilst often left unpeeled (coated ginger). The ginger is then sun dried and, if peeled, is dusted with lime. It is sometimes ground before sale. Ginger is also preserved in sugar syrup or candied with sugar. An infusion of ginger in alcohol, "tincture of ginger," is very commonly used in medicine in the treatment of indigestion. Turmeric, used for a dye and in curry powder, is the rhizome of a similar plant to ginger.

**Cinnamon.**—Cinnamon is the inner bark of the youngest twigs of a Cingalese tree (*cinnamomum zeylanicum*) and also of similar growths from the cassia tree of China, Burma, etc. Ceylon cinnamon is regarded as the best. The bark is rolled up into sticks for the market. Cinnamon is much used in Southern Europe as an ingredient in incense. Cinnamic aldehyde, the chief flavouring matter in cinnamon, is now synthetically prepared.

**Vanilla.**—Vanilla is a flavouring very commonly used, especially in cocoa and chocolate. It is also used in the preparation of perfumes. The vanilla plant (*vanillin planifolia*) is a climbing orchid and bears beans which are picked unripe and fermented, and then as a rule extracted with alcohol. The best vanilla comes from Mexico, but much comes from Mauritius, Tahiti, and Bourbon. Vanillin, which is the chief flavouring matter in vanilla, and forms about 2 per cent of the beans, is now made artificially on a fairly large scale from benzaldehyde and also from oil of cloves. It is methoxy paraoxy benzaldehyde.

Vanilla is much adulterated with tonka beans, the characteristic flavour of which is due to cumarin, which can also be artificially made.

**Bitter Almonds.**—Both bitter and sweet almonds are grown in the Mediterranean area. Although similar in appearance they differ very greatly in flavour. Oil of almonds, *i.e.* the oil expressed from sweet almonds, is similar to olive oil, whereas oil of bitter almonds contains benzaldehyde as well as, in the first place, the deadly poison known as prussic acid (hydrocyanic acid). There are cases on record of persons dying from eating a dozen or so bitter almonds. The principal flavouring matter is the benzaldehyde, although prussic acid and mandelonitrile also have a bitter almond-like smell. All of the oil of bitter almonds or almond flavouring on the market is artificially produced benzaldehyde, except the official preparation for the pharmacopoeia. Benzaldehyde is prepared chiefly from lead nitrate and benzyl chloride.

**Vinegar.**—Vinegar is a condiment which has been in use from antiquity, and its solvent action on calcium carbonate (pearl) is classic knowledge.

Vinegar is impure acetic acid ( $\text{CH}_3\text{COOH}$ ) and results from the oxidation of many common substances, including alcohol. Such

oxidations can be effected inorganically or by the aid of living ferments, and it is these latter forming acetic acid from alcohol which cause the souring of beers and light wines. Fortified wines, such as "port," are untouched because the alcohol kills the ferment.

Vinegar is made by the slow or more rapid oxidation of the alcohol in a beer (malt vinegar) or a wine (wine or white vinegar). In the quick process, which is more generally used, the vinegar is made to pass very slowly through barrels containing beech shavings which have been previously immersed in vinegar so as to become coated with a culture of "*mycoderma aceti*," the necessary bacteria.

Vinegar so prepared contains many substances besides water and acetic acid, and it is to these esters, etc., that its characteristic smell and taste are due. Inferior vinegars are produced by the distillation of wood.



## CHAPTER XX

### TOBACCO

**TOBACCO.**—This is one of the most universally used of substances. It was unknown in Europe until its introduction from America by Spaniards in 1558, and by Sir John Hawkins in 1565, although at that time it was in general use throughout the whole of non-arctic America, and was consumed as snuff, as cigars, and in a "tobacco," pipe. From one of these pipes, a forked cane with two mouth- or rather nose-pieces (for smoke was inhaled through the nostrils), the substance took its name. Sir Walter Raleigh cultivated it in Ireland and established settlements in Virginia which subsequently lived by their yield of tobacco. In fact, the cultivation of tobacco in the first North American colonies was so general that tobacco itself passed for currency. Tobacco attained an enormous vogue throughout Europe, but came under a ban, especially in Turkey, Russia, and at Berne. However, this was only a check, and a belief in its fumigating and disinfecting powers led even to its use as incense in the churches. During the great plague in England children even were taught to smoke as a protection, and we find that shortly afterwards the consumption of tobacco per head in Britain was as great as it is to-day.

In Georgian times smoke tobacco went rather out of fashion and gave place to its consumption in the form of snuff to such an extent that the proper taking of snuff became a social art. Many governments now impose heavy duties on tobacco and some restrict its sale to people over 16.

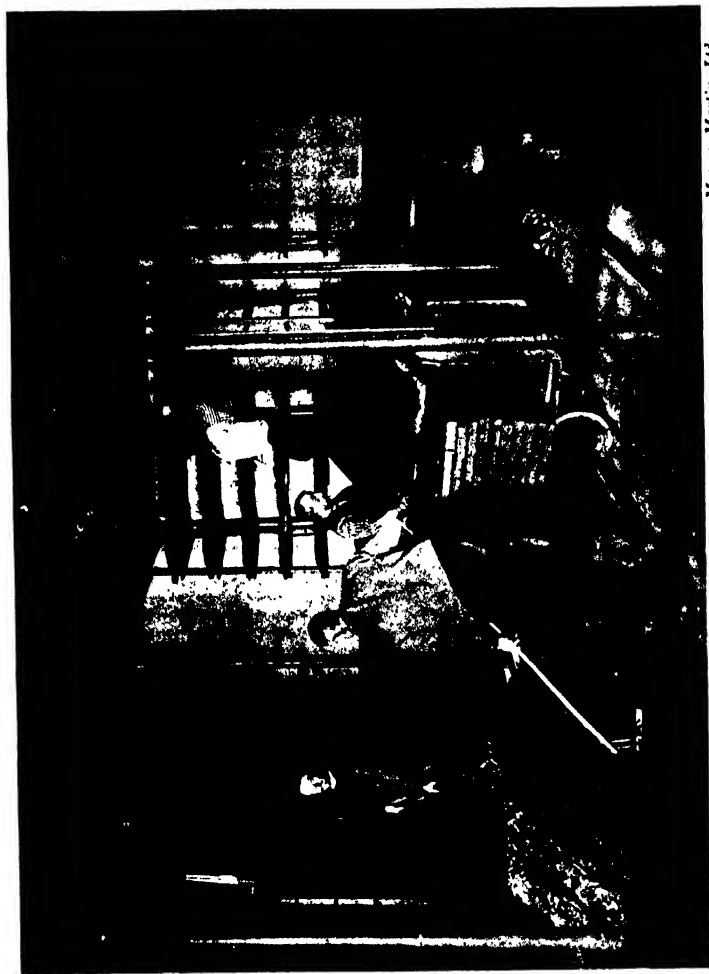
The tobacco plants usually grown commercially are *nicotina tabacum* (generally) and *nicotine rusticum* in Hungary and Sumatra, etc. It is a tender plant but can be planted out after likelihood of frost is over in all temperate countries. It is raised annually from seed. The young plants are transplanted to stations about 3 ft. apart on heavily fertilized ground. Nearly a quarter ton per acre of good nitrogenous manure is required. Sometimes in America this is partly furnished by the cultivation of a vetch, which also serves to protect the young plants. All side shoots are removed, and

when the plants have about a dozen leaves, *i.e.* by September in the Northern Hemisphere, they are lifted on a sunny day, left till the evening, and then hung up in sheds with a regulated temperature of about 30° C. to dry. The leaves are then heaped together as though to make leaf mould, and left to ferment with special cultures for about two months. Too much decomposition is prevented by loosening and turning over the heaps daily. The flavour and aroma of the resultant tobacco are largely dependent on the process of fermentation, and it requires a good deal of skilled attention. The fermented leaves are then tied in small bundles or bands (six leaves each), dried and exported to the manufacturer. The further manufacture consists in removing the mid-rib of the leaf, which is subsequently chopped for snuff, and then cutting the leaf; for birds' eye tobacco, however, the mid-rib is not removed. Of course, if cigars are to be made, the leaves are rolled and not cut.

The tobacco plant is inordinately sensitive to local conditions and the same soil will yield a different tobacco within a distance of a few miles with no discernible change in climate. Thus, good Havana tobacco cannot be grown too near the sea in Cuba. This variation with conditions would be very unpleasant if it were not for the fact that there are pronounced, and different, national tastes in tobacco. America, for instance, exports very little of the type of tobacco she herself consumes, and the kind of tobacco she sends to England (which is the best) is quite different from that she exports to Germany. The problem is to find the best and most marketable tobacco for each area, and this has been very carefully investigated by the United States Government.

The chief tobacco-producing countries are U.S.A., which produces over a quarter of the world's crop (principally in Kentucky and the adjacent states), Mexico, Cuba, and Central America and West Indies generally, Northern South America, Austria, Hungary, Holland, Russia, Germany, Turkey, Greece, and the Aegean Islands, Bulgaria, India, East Indies, China, Japan, Australia, Rhodesia, Transvaal, Egypt, etc.

There is not much doubt that tobacco would do quite well in England, but two things militate against it: the fact that the British farmer will hardly stand the rigorous inspection of the excise



*Messrs. Marlin, Ltd.*

TOBACCO DRYING-ROOM FILLERS

*By permission of*

department, and also that the kinds of tobacco produced (similar to Boer tobacco) are not such as appeal, at present, to the British smoker.

The reason why so many people smoke in so many different parts of the world is difficult to give. It is well known, of course, that tobacco contains nicotine, a poisonous narcotic alkaloid, but it is very doubtful whether under the usual conditions of smoking, especially in a pipe, any nicotine is absorbed by the smoker at all, and further the writer personally does not know of any smokers who will admit feeling any narcotic effects from smoking. Many say they work better for a pipe and some say the effect is sedative.

**OPIUM.**—In various parts of the world other substances are used in much the same way as tobacco. The chief of these is opium, which is the dried juice from the seed pod of the opium poppy. This poppy is grown in Bengal, Malaysia, China, Asiatic Turkey, and Persia. Opium is smoked in special pipes, especially in China, although the practice is prohibited there. Each pipe yields a few whiffs only.

From opium, laudanum, morphine, and cocaine are prepared. The substance itself and the various preparations from it are strong narcotic poisons which, however, can be taken in increasing quantity through use.

Kola nut, areca or betel nut, and coca leaves are chewed similarly to tobacco for stimulating or sustaining properties.

## CHAPTER XXI

### DRUGS

**DRUGS.**—These are substances which have a relatively larger effect on living things than their ordinary foods, but there is, of course, no hard and fast distinction. Thus brandy or tea can be regarded as either a food or a drug. In ordinary circumstances, however, the name “drug” is applied to such bodies as are administered to sick persons only, or to substances small quantities of which have an ultimately deleterious effect on healthy people.

Even here, however, we are at variance with common usage, since very many of the common medicines, especially those of mineral origin such as Epsom salts or bicarbonate of soda, are not generally recognized as drugs at all. Strictly speaking, drugs can be administered to plants and the lower animals but we shall here confine ourselves to such as are taken by man.

Drugs are administered for general or special purposes and to have effect on particular organs or upon the body as a whole. Usually probably drugs are taken with the object of producing particular or local effect only, but it is very difficult to find natural substances the effects of which are so restricted. The first step towards so doing is the isolation of one particular chemical substance out of the complex of which the natural substance usually consists. Then careful chemical study of this substance, and the study also of its physiological effects may lead to the conclusion that the desired property lies in a particular chemical grouping only, other groups present having no effect or being positively harmful. Or the addition of another group of atoms to each molecule of the drug may increase its good or diminish its evil effects or localize its effect. Thus, in the treatment of rheumatism and some nervous disorders an infusion of willow bark used to be given. The efficacy of this was due to a glucoside called salicin ( $\text{C}_6\text{H}_{11}\text{O}_5$   $\text{C}_6\text{H}_4$   $\text{CH}_2\text{OH}$ ), which can be prepared pure and was therefore given in place of the infusion. But it was subsequently found that the beneficial action of salicin was due to salicylic acid ( $\text{C}_6\text{H}_4$   $\text{OH}$   $\text{COOH}$ ), and that substance was made and administered. Salicylic acid is, however, practically insoluble in water and difficult of absorption, whereas its sodium salt is much more easily soluble and absorbed, consequently sodium

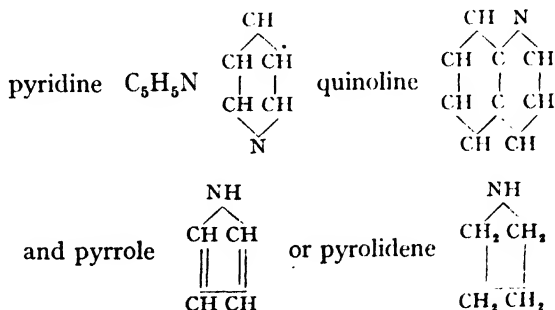
salicylate was given in place of salicylic acid. All of the foregoing substances have, however, a deleterious effect on the intestines since they are preservatives and hinder digestion, but it was found that the addition of an acetyl group to the salicylic acid molecule produced a body, acetyl salicylic acid ( $C_6H_4O \cdot CO \cdot CH_3 \cdot COOH$ ), which had practically no harmful digestive effect and yet whose beneficial action was unimpaired. It is in this form that the drug is now almost always taken, and it is sold under the well-known names of aspirin, genasprin, regepyrin, etc. A sodium salt of this is now used under the name of "soluble aspirin."

The modern tendency is, of course, towards the production of drugs of increasingly specific local action.

**THE ALKALOIDS.**—One of the most important classes of physiologically active substances is the alkaloids. They may be described as "nitrogenous substances of vegetable origin and pronounced physiological action," as "a vegetable base which contains a cyclic nitrogenous nucleus" (Cohen), and by many other definitions, none of which, however, includes all bodies which are alkaloids, and at the same time excludes all substances which are not alkaloids.

In a study of the alkaloids it is difficult to avoid chemistry, and although a physiological classification can be made yet a chemical one is probably the most logical. Since, however, we are here concerned only with the more important alkaloidal drugs, most of the 200 odd known alkaloids, and their many artificial prototypes, may be ignored.

Alkaloids can be classified according to their chief degradation products, and these are



All of these substances are important, not only in the drug industry but in the dye industry as well. To obtain them bones from which the fat has been removed are distilled in iron retorts. Bone charcoal (see Sugar and Carbon) is left behind in the retort whilst the gaseous distillates are used for heating or lighting. The liquid distillate settles in two layers, an aqueous solution of various ammonium salts, *e.g.* sulphocyanide or thiocyanate, cyanide, sulphide, carbonate, etc., and an oily layer. From the aqueous solution ammonia (mainly) and other bases are prepared by acidification with sulphuric acid, and then making alkaline with potash or caustic soda. The oily layer and the non-ammonia bases are then redistilled into many fractions and many substances, including pyrrole, quinoline, and pyridine, result. (Bone oil has a filthy smell and it is used for denaturing alcohol.)

The pyridine alkaloids are relatively simple bodies, but none of them is as yet of commercial importance, although one of them, piperine, is an important constituent of pepper, and another, coniine, is the chief ingredient of such an infusion of hemlock as poisoned Socrates.

**Quinine.**—Some of the quinoline alkaloids are, however, important commodities, especially quinine. Quinine is present in the bark of all cinchona trees, but it is a drug of such great importance that great care has been used in the breeding and selection of trees with a high yield of pure quinine. The cinchona trees were native to the tropical Andes, but are now reared in South India, Ceylon, and Java, well up the mountain sides. The most important tree at the present time is a hybrid cinchona (*ledgeriana*). If cinchona trees be grown below an altitude of 6,000 ft. the yield of quinine is very much reduced.

Cuprea bark (hard bark), the bark of *remijia pedunculata*, a tree native to Colombia, although containing only a small quantity of quinine is so much cheaper than cinchona bark as to be used extensively for the preparation of quinine. The young trees are reared in various ways, but the green shoots which grow from cinchona trees after they are cut down, form the usual stock. The trees come into bearing when they are about eight years old, and then the bark is peeled off in discontinuous strips so that some bark is always left on. By this means not only is the tree uninjured,

but the new bark, with an increased yield of quinine, grows over the stripped rings at a greatly increased rate. The yield of quinine from an individual tree reaches a maximum at about eleven years old. The bark, after removal, is finely milled and the resultant powder treated with slaked lime. By this means the bases (quinine, cinchonine, quinidine, etc.) are set free, and the whole mass is evaporated dry when the alkaloids are dissolved out in alcohol. The alcoholic solution is then evaporated to dryness and a bare minimum of boiling dilute sulphuric acid added. The alkaloids dissolve, but quinine sulphate, unlike the others, is so difficultly soluble in cold water that on cooling that solution it crystallizes out approximately pure. It can be purified by recrystallization and put on the market as quinine sulphate, quinine bisulphate (very soluble in water), quinine hydrochloride or citrate of iron and quinine.

Quinine in small doses promotes the formation of digestive juices and thus increases the appetite, and so acts as a tonic. It is mildly antiseptic and non-irritant, but its great virtue is its effect upon the "haematozoon malariae," the organisms responsible for malarial fever. These it almost completely destroys, except, and importantly, during the actual paroxysmic attack, when it is of no use. Quinine is also a great preventive (prophylactic) against malaria. Considering the large doses which are administered (up to 30 grains of sulphate) quinine has strangely little undesirable effects.

In view of the practical indispensability of quinine it is of great importance that, with the exception of quinidine, which is sufficiently valuable to warrant its extraction, the alkaloids found with it in cinchona bark are not only non-deleterious but even have the same action as quinine. The purification of quinine is, therefore, not nearly so expensive as might otherwise be the case.

Quinine itself is a white, silky, crystalline substance which melts when anhydrous at  $177^{\circ}\text{C}$ . It was first isolated by Pelletier and Caventou in 1820. It is soluble in hot water, alcohol, chloroform, and ether, and has a bitter taste.

Quinine is a methoxy cinchonine, and this latter substance also occurs in cinchona bark. Cinchonine, which forms white prismatic



crystals melting at  $255^{\circ}\text{C.}$ , has a similar though less pronounced therapeutic action to quinine, and is usually present in samples of commercial quinine.

**Strychnine and Brucine.**—The same two investigators who isolated quinine from cinchona bark, had in the two previous years obtained two crystalline alkaloids from *Strychnos nux vomica* (India, Persia, and Queensland), which are called strychnine and brucine respectively, and both of them probably belong to the quinoline group of alkaloids. Both alkaloids are also found in St. Ignatius's bean.

The free alkaloids are obtained similarly to quinine by treating the ground nut, or bean, with slaked lime to set free the bases and then extracting them with a suitable solvent, *e.g.* chloroform. The sulphates are then formed and the alkaloids separated by extraction and recrystallization. Both substances have a similar physiological effect, but the one always used in medicine is strychnine. This is a colourless substance melting at  $284^{\circ}\text{C.}$  and with an intensely bitter taste. In small doses it acts as a valuable tonic, improving the appetite, and is especially useful to persons recovering from an enfeebling illness. In larger doses it greatly increases the heart's action, whilst larger quantities still (although still very small in themselves) are violently poisonous, producing convulsions and tetanus.

Strychnine is usually given medicinally for its tonic effect in the form of its phosphate or hypophosphite, especially in Easton's syrup and Fellowe's syrup.

There is no effective antidote in cases of strychnine poisoning. The only thing to do is to remove the poison by emetic or stomach pump and prevent the convulsions by narcotics, *e.g.* chloral or chloroform.

**Veratrine** is another quinoline alkaloid used in medicine. It is obtained from *sabadilla* seeds (Mexico), and is used as an external local anaesthetic. Internally it is very poisonous.

**THE OPIUM ALKALOIDS.**—Opium is obtained from the white poppy (*papaver somniferum*) cultivated in Asia Minor, India, Malaysia, and China. The seed capsules are picked before they are ripe, and when scratched so as to break the surface a white milky juice flows out which is allowed to dry in the air. This is

opium. It contains many alkaloids, the most important being—

Morphine, 9 per cent	Papaverine, .8 per cent
Codeine, .3 „	Narcotine, 5 „
Thebaine, .4 „	Narceine, .2 „ ( <i>Richter</i> ).

Medicinally, opium is usually administered as a tincture called laudanum, prepared by macerating opium with water and extracting with alcohol. It contains .75 grams of morphine per 100 c.c., and to this its action is chiefly due.

Although opium and laudanum are still prescribed for general anaesthesia to pain yet, generally speaking, it is the alkaloid morphine which would be administered nowadays where opium would have been given formerly.

**Morphine**, the first alkaloid to be isolated, is a white crystalline substance forming a crystalline hydrochloride, which is the official preparation. It produces stimulation, painlessness, and sleep according to the dose. In large doses it is, of course, highly poisonous.

Most of the opium alkaloids contain the isoquinoline nucleus, but morphine, thebaine, and codeine do not.

**Narcotine**, the chief alkaloid in opium after morphine, is used in the treatment of ague.

**THE PYRROLIDENE ALKALOIDS.**—The pyrrolidene alkaloids include some of the most valuable and most interesting members of the group, and it is in their direction that the greatest synthetic advances have been made.

The substances most commonly known are all derivatives of tropine.

**Atropine** is the mydriatic substance in belladonna, and it is because belladonna contains atropine that it is so widely used in the examination of the eye. Atropine usually occurs naturally along with hyoscyamine and scopolamine, and it is more than probable that it is only obtained by the effect of the extractive process upon hyoscyamine, and is not present at all in the plants. The plants chiefly used are belladonna (*atropa belladonna*), henbane (*hyoscyamus niger*), and stramonium (*datura stramonium*).

The alkaloids exist in all parts of the plant, and are obtained

by the percolation of 90 per cent alcohol through the powdered dried plant. On the removal of the solvent a gummy mass remains which is treated with dilute hydrochloric acid. The bases are set free by alkali and extracted with chloroform. Hyoscyamine crystallizes out on the addition of light petroleum, and the more soluble scopolamine can be obtained subsequently. All the atropine of commerce is prepared by allowing hyoscyamine to stand with dilute sodium carbonate solution.

Both atropine and hyoscyamine are strongly mydriatic, but atropine is used almost exclusively in practice. According to Thorpe one part of atropine in 130,000 parts of water is sufficient to dilate the pupil of a cat's eye.

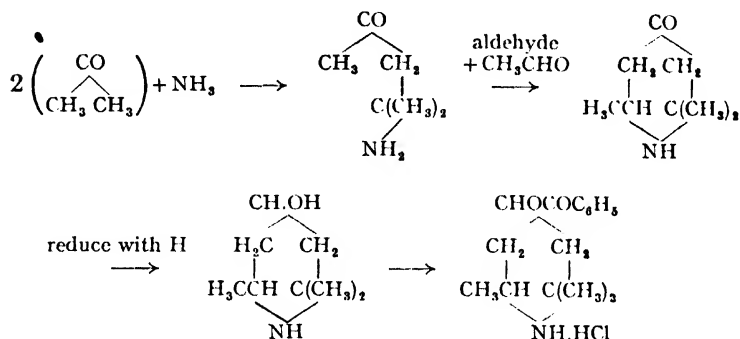
Scopolamine, which is also powerfully mydriatic, is having a rapidly increasing use in that it produces local anaesthesia in child-birth (twilight-sleep).

**Cocaine** is another alkaloid closely allied chemically to the foregoing. It is prepared from the leaves of *erythroxylon coca*, which is cultivated for the purpose in Peru, Bolivia, Java, and the Federated Malay States. Cocaine is prepared by pounding and shaking with alkali (sodium carbonate) and petroleum. The solution in the paraffin is then extracted with hydrochloric acid from which impure cocaine hydrochloride can be crystallized out. The pure hydrochloride (market form) is obtained from the crude product by solution in water, making alkaline with soda, and redissolving the precipitated base in alcoholic HCl, from which solution the pure hydrochloride will crystallize out.

Cocaine is, in very small quantities, a stimulant, and the practice of chewing coca leaves and kola and betel nut depends on this property of cocaine. In larger doses, and by injection, cocaine produces local anaesthesia, and has been employed very largely for this purpose in minor operations, *e.g.* dentistry. A careful study of the relation of other groups to the N atom in cocaine and exhaustive physiological tests have led to the synthesis of substances chemically similar to cocaine, which, however, have not its poisonous and mydriatic properties so highly developed, and which can be used according to their properties for either major or minor operations.

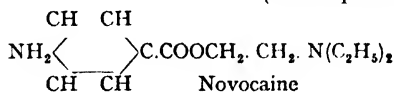
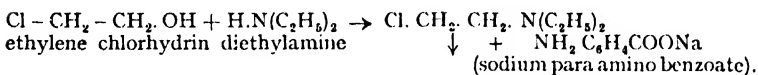
One of these which can be used for major operations is  $\beta$  eucaine.

It is now prepared on a fairly large scale by adding ammonia to acetone and condensing the diacetoneamine produced with aldehyde to form vinyl diacetoneamine.



The vinyl diacetoneamine is converted into vinyl diacetoneamine alkamine by sodium in amyl alcohol, and benzoyl chloride, and subsequently hydrochloric acid, convert this into  $\beta$  eucaine.

**Novocaine**, which is used in minor operations and has practically replaced cocaine in dentistry, is prepared from diethylamine, which is prepared from diethyl aniline, an important intermediate product in the dye industry.



Novocaine in its usual doses has no toxic effects. It is usually used in conjunction with adrenaline and chloretone.

**Adrenaline** is the principle in the suprarenal gland which controls the blood pressure of the body and was first isolated by Takamine. It conforms with the definition of an alkaloid in all except that it is of animal and not vegetable origin. It is of great use in operations, since by contracting the blood vessels in the field of operation it prevents bleeding and much reduces the use of swabbing, etc. It is used for open "scraped" wounds.

Adrenaline has been synthesized and the synthetic product has cleared the natural one from the market and greatly reduced its price.<sup>1</sup>

Other medicines of animal origin include thyroid gland preparations, which are usually prepared from the thyroid glands of sheep. They are of very great importance in the treatment of goitre.

**ANAESTHETICS OTHER THAN ALKALOIDS.**—**Chloroform** ( $\text{CHCl}_3$ ) is prepared on a very large scale by the action of bleaching powder on alcohol. The chloroform can be distilled off and purified by redistillation. It is a colourless, heavy, refractive liquid boiling at  $61.2^\circ\text{C}$ . When inhaled it produces complete anaesthesia, which can be continued over a very long period. It is undoubtedly the most valuable anaesthetic known and, all things considered, the safest. When first used fatalities were not infrequent, but these were probably due to poisoning by phosgene ( $\text{COCl}_2$ ), which is generated by the action of sunlight on chloroform. When chloroform is kept in a full bottle in the dark it is quite stable. When ethyl chloride is mixed with chloroform no ill consequences at all are experienced. Chloroform is not only anaesthetic but antiseptic as well, and it is used in operations to sterilize organs and prevent complications, *e.g.* the intestines. Apart from its medicinal use, chloroform is a very important solvent, particularly in the purification of the alkaloids.

In addition to chloroform most of the halogen derivatives of methane and ethane are anaesthetics, and many of them have been used. The one that has had the greatest vogue, however, iodoform ( $\text{CHI}_3$ ), has always been used on account of its antiseptic properties and not as an anaesthetic. It is a yellow, strongly-smelling crystalline substance prepared from iodine, alkali, and alcohol. It is now, however, very largely superseded.

**Ether** (sulphuric ether)  $(\text{C}_2\text{H}_5)_2\text{O}$ , prepared by the action of sulphuric acid on alcohol and subsequent distillation of the ether produced is used as an anaesthetic mainly because of the freezing effect it produces when rapidly evaporated. It is a light, colourless, highly inflammable liquid boiling at  $34^\circ\text{C}$ ., and is of great

<sup>1</sup> Preparations similar to adrenaline are prepared from supra-renal glands of animals slaughtered at Chicago.

importance as a solvent since most organic substances dissolve in it and it is chemically inert.

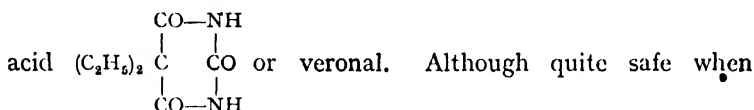
**Trichlor butyl alcohol**  $[C Cl_3(CH_3)_2 C OH]$  or chloretone, is an anaesthetic used in dentistry and as a sedative for sea-sickness.

Closely allied to the anaesthetics are the hypnotics, and of these there are a great number. Hypnotics differ from narcotics in that narcotic sleep is pathological whereas "hypnotic"-ally produced sleep appears to be normal sleep.

One of the most valuable is "chloral" ( $C Cl_3. CHO$ ), but since it has a bad effect on the intestines certain derivatives are now used as well, of which it is argued that there are no deleterious effects.

**Acetophenone**, or hypnone, phenyl, methyl, ketone ( $C_6H_5CO CH_3$ ) and sulphonal  $(CH_3)_2C(SO_2C_2H_5)_2$  are hypnotics, and the latter is very widely used.

Similar in action and still more generally used is diethyl barbituric

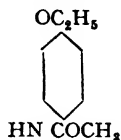


properly administered large doses are toxic, and the very general use of veronal has led to such fatalities as have caused it to be included amongst the non-procurable poisons.

**ANTIPYRETICS.**—**Quinine** is one of the most important antipyretics, but that has been already dealt with. Some others have been synthetically prepared from coal tar residues, including acetanilide, made by heating up acetic acid with aniline and crystallizing the product.

**Acetanilide** ( $C_6H_5 NH COCH_3$ ), or anti-febrine, is a white pearly crystalline substance melting at  $112^\circ C$ . It is pronouncedly antipyretic, and is also of use in the treatment of rheumatism. It was the first synthetic drug, but it has unpleasant after effects, and various preparations have since been made which tend to replace it in practice, since they are much less toxic in their effects. One of the chief of these is exalgin, or methyl acetanilide ( $C_6H_5 N .CH_3COCH_3$ ), which is a specific for neuralgia. It consists of crystalline needles, melting at  $101^\circ C$ ., which have a very curious sharp motion when placed on the surface of water. Another still more important

substitute is para ethoxy acetanilide, melting at  $135^{\circ}$  C. which is the very well known and much used substance "phenacetin."



Other important antipyretics are antipyrine and its derivative pyrazolone. It is curious that such a valuable drug as antipyrine should have resulted from an attempt to build up quinine-like substances at a time when the structure of quinine was wrongly conceived. Yet in spite of this vital initial mistake a highly valuable antipyretic was obtained. The first substance produced by the condensation of phenyl hydrazine with aceto-acetic ester was phenyl methyl pyrazolone, but it proved to be practically useless therapeutically. But previous experiment had shown that methylation had greatly increased medicinal value, and following upon this phenyl dimethyl pyrazolone (antipyrine) was prepared. Pyrazolone, or phenyl dimethyl dimethylamino pyrazolone is more efficient and safer than antipyrine.

Salicylic acid and aspirin have been treated in the introduction to this chapter.

**ANTISEPTICS.**—The preparation and manufacture of antiseptics and disinfectants is quite an important industry and chemists are continuously evolving new substances to secure increased sterility or sterility without injury to specific tissues. Many of the inorganic antiseptics and disinfectants have already been mentioned and they will not be again treated here except to mention that bodies which evolve chlorine, iodine, or oxygen are especially valuable, whilst mercury, bismuth, arsenic, and silver are also very important. Much, indeed, of the modern work consists really in finding compounds of these elements which shall act as vehicles for them and ensure their liberation under required conditions.

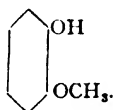
Of the purely organic antiseptics formaldehyde and the phenols require special mention.

**Formaldehyde** ( $\text{H CHO}$ ) is prepared on a large scale by passing a mixture of methyl alcohol vapour and air through red-hot copper tubes or gauze. The impure formaldehyde can be condensed to a

liquid and purified by redistillation. Formaldehyde is a gas which condenses to a liquid of boiling point— $21^{\circ}\text{C}$ . It is soluble in water and is often sold as a 40 per cent solution in water under the name of formalin. It has a hardening effect on gelatine and on the surface of bacteria, which are thereby rendered unable to develop. It is used otherwise than as an antiseptic on a large scale—for its gelatine hardening properties in the tanning of leather and in photography—as a reducing agent in the preparation of mirrors, etc., and, again, in photography. It is almost indispensable in various chemical and dye industries. As a preservative it is handicapped by the fact that it is an irritant poison, but of course this does not affect its use in the preservation of articles other than foodstuffs, *e.g.* corpses, nor in practice does it prohibit its use in the preservation of certain foods, *e.g.* meat and beer.

Since formaldehyde is irritant, various derivatives lacking this unpleasant property have been prepared for medical and surgical use.

**The Phenols** are all antiseptic. They are made by the direct distillation of coal tar, and phenol, or carbolic acid, is also made from benzene. Most of the phenols are irritant and toxic and many derivatives have been prepared for special use. One of the most important of these is guaiacol, or methyl pyrocatechol. It is used as an internal antiseptic in the treatment of phthisis.



Fossil fish are distilled and one of the resultant bodies after sulphonation is the well known ichthyol.

**PERFUMES.**—Closely allied to the preparation of drugs is the preparation of perfumes. As is the case with drugs, whilst all the original perfumes were naturally occurring bodies many of them are now produced artificially in the laboratory and the factory. These include esters such as oil of wintergreen (methyl salicylate) and terpene derivatives, such as pseudo ionone, which has the odour of the violet. Nothing, however, has yet been done in the direction of synthesizing new scents since the relations between chemical constitution and the effects upon the olfactory nerves are not yet known.



## SECTION IV—MATERIALS OF MAINLY ORGANIC ORIGIN NOT PREVIOUSLY CLASSIFIED

### CHAPTER XXII

#### CERTAIN PLANT-JUICES AND THEIR SUBSTITUTES

**GUTTA PERCHA.**—Gutta percha is the coagulated juice from the bark of certain trees of the *Sapotacea* family, the chief being *palaquium gutta*. This is a big forest tree with small glossy leaves. The full origin of the name "gutta percha" is not certainly known, but "gutta" or "getah" is the Malay for a juice which flows from a tree. The trees are native to a very small area in the Malay Peninsula, and to certain of the East Indies. They have been transplanted to, and are now cultivated in, Java.

Gutta percha is obtained from the inner bark of the tree and is collected by tapping, *e.g.* making cuts in the bark. Unfortunately, however, it coagulates so easily that laborious and continuous tapping is necessary in order to secure a full yield of the substance, and this has led to the practice of cutting down the trees and making large cuts right round the trunks. Where the trees are cultivated, however, they are tapped similarly to rubber.

Gutta percha is also present in the leaves of the trees and various methods have been tried to obtain it from them. Gutta percha when first collected contains dirt, gum, resin, and much other impurity. A preliminary purification, consisting of boiling with water, is carried out at the collecting station, after which it is exported. The refining consists in working it whilst warm in various ways, one of which is to filter it under pressure through metal gauze whereby much of the dirt is removed. It is also rolled.

Gutta percha is a hard resilient elastic substance, impervious to water, alkalies, and some acids. It is a non-conductor of electricity,

and finds its chief use as an insulator, especially for cables, etc. When warm (190–200° C.) it is plastic and can therefore be moulded, and it retains the same shape without impaired properties when cooled again. It is used for the outer covers of golf balls and for dental and surgical purposes. Chemically it appears almost identical with rubber.

Balata is a substance similar to gutta percha, from Guiana.

**RUBBER.**—Rubber, india rubber or caoutchouc, was first observed by Europeans when the Spaniards discovered South America. They found the native children playing with balls composed of it. They soon realized that it was derived from trees and adopted the plan of waterproofing their garments by smearing the latex over them over 300 years before this was done in Europe. The Spaniards also found that it would remove pencil marks by rubbing and called it indian rubber. The trees from which it is obtained were not carefully examined until 100 years ago. They have proved to be *havea brasiliensis*, or the Para rubber tree; *manihot glaziovii*, or the Ceara rubber tree; the *castilloa elastica*, or Ule rubber tree; *Ficus elastica*, which is the ornamental rubber plant of the European conservatory, but which grows to a large tree in Northern India and Assam, and various vines of the order *apocynaceae*. There is native to Tonking a tree (*bleckrodia tonkinensis*) which may produce commercial rubber in the future, whilst the Mexican shrub Guayule (*parthenium argentatum*) also, at present, furnishes supplies of rubber. All of the foregoing trees require tropical and humid conditions with a retentive soil, and will not yield well when the minimum temperature falls below 22° C. (72° F.), whilst a rainfall of as much as 100 in. per annum appears desirable unless the trees are close to a natural ground water supply. Standing water about the trees is not, however, a good condition.

Rubber, therefore, comes from tropical and equatorial regions, *i.e.* the Amazon basin, Guiana, Central America, Mexico, Central Africa, including the Congo basin, the Sudan, Assam, Ceylon, Malaysia, and the East Indies. The shrub guayule alone flourishes outside these areas, *e.g.* in N. Mexico and S. Texas.

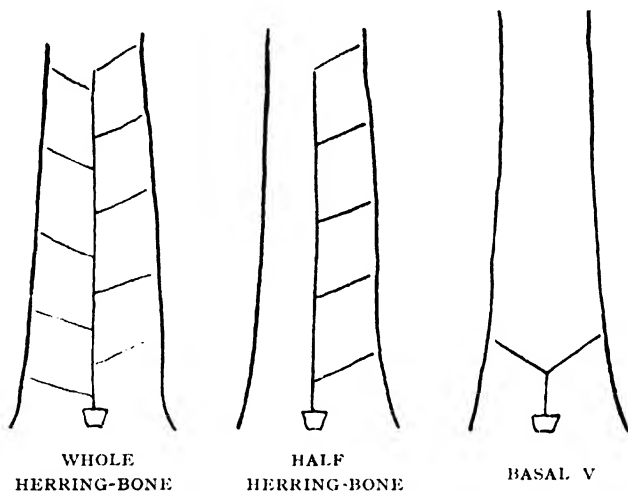
Most rubber has been derived from forestal trees and vines, but in the last twenty years great strides have been made with the cultivation of rubber trees as a plantation product, and since such

plantation rubber could be marketed at prices equal to or less than those obtaining for wild rubber, it seems that in the future plantations will be the only important source of the article. This will be helped by the fact that the Amazonian forests are not such as are usual in Europe, *i.e.* great groups of trees of one kind, but rather mixtures of many different kinds of trees. Collection under such conditions is very expensive, and will become more so since wasteful methods of collection will lead to the more easily accessible sources becoming worked out.

On the plantations the Para rubber tree (*havea brasiliensis*) has been found the most profitable, and up to 2,000,000 acres have already been cleared and planted. Generally the young plants are raised in a nursery and planted out, about 150 to the acre, but, occasionally, the seeds are planted where the trees are to grow in the open ground. The trees do not come into bearing until they are from six to eight years old, and the task of weeding for the long period which must elapse before the trees reach overhead, and, by shutting out the light, prevent weed growth, is very arduous and expensive. Catch crops, such as cassava (tapioca), tea, cocoa, and coffee, are sometimes grown with the double purpose of keeping down the weeds and securing a quicker return on the capital outlay, but a better plan is probably that of planting vetches and digging them in. These plants, besides growing very quickly, greatly enrich the nitrogen content of the soil. Plantation rubber has not hitherto been of quite as good quality as the best wild rubber, but since the best wild rubber is known to come from the older trees it may well be that this deficiency is merely due to the comparative youth of the plantation trees. It is greatly to the advantage of the planters that rubber, unlike a fruit or grain crop, is not ripe at a particular season only, deteriorating if not harvested at that time. On the contrary, it is better for rubber trees that they should not be tapped too frequently. Therefore if the market for rubber is bad the trees can be left untapped until, with the return of a good market, a natural accumulation is all ready to be collected.

It has been stated that rubber is a latex. It is not a sap, and does not appear to have anything to do with the normal nourishment of the tissues of the tree. It is usually secreted in the inner

bark, but may be present also in the roots and leaves. It is a true emulsion, consisting of tiny globules of liquid rubber in suspension in a watery serum very similar to the particles in milk. Further, to the analogy with milk it forms a sort of cream on the surface of the serum if left to stand and it can be curdled or coagulated.



There are different methods of collection in different areas. The shrub furnishing guayule rubber is too small to be tapped and is therefore uprooted and macerated bodily with water, but since it is expensive and difficult to propagate and cultivate this will probably mean that it will soon cease to be a commercial competitor with other supplies.

The trees have been treated in damaging ways in the past, even to the length of cutting them down, but the general practice now is to make incisions in the bark with a very sharp instrument, which is so formed as to prevent its cutting too deeply and injuring the trees. The cuts are either V-shaped, spiral, herring-bone or half herring-bone.

The latex flows out into cups fastened beneath. A very small amount ( $\frac{1}{32}$ " ) of bark is cut away each time and the operation is usually renewed every other day for a period of six weeks or so.

When the whole of the bark, to a height of about 6 ft. from the ground, has been treated the tree must rest for from three to four years before it can again be tapped. The yield varies considerably and increases according to age ; averages of as little as  $\frac{1}{2}$  lb. (young trees) to as great as 5 lb. per tree per year are experienced, but 3 to 4 lb. is about the usual.

The latex, after collection, requires to be coagulated. On the Malay plantations this is usually done with small quantities of acetic acid, but on the Amazon a sort of paddle is dipped into the latex and held in the smoke of a fire in which nuts of the urucuri palm are burned. As soon as the first layer hardens the paddle is re-dipped and re-smoked, and the operation repeated until a lump of rubber of from 20 to 100 lb. weight is deposited in thin layers. It is then removed for export. This process is supposed to be the best, and Para rubber so treated commands the highest market price (hard Para).

The manufacture of rubber did not become appreciable until the discovery of vulcanization resulted in the production of a substance much less adversely affected atmospherically than is crude rubber, and the additional discovery by Macintosh (first in point of time) that rubber could be dissolved in naphtha and re-deposited from solution. These discoveries and the rapid development of the electrical and motor industries have enormously stimulated the production of, and the demand for, rubber.

The first stage in manufacture is the production of dirt free dry rubber, and in this connection it should be noted that plantation rubber is exported dry and comparatively clean, whereas wild rubber is wet and dirty. The crude rubber is boiled for hours until it softens and then sheets are cut and rolled in a stream of water. The cleaned product is then dried at a low temperature, preferably *in vacuo*.

The further treatment depends on the purpose for which it is required. If the very finest rubber, suitable for tobacco pouches and air balloons, is required the dry product is warmed until quite plastic, kneaded, and then compressed into cylindrical or rectangular blocks. These are frozen hard and then shaved by slicing knives, or the cylinder revolves and a turning of thin rubber

as long as required, and up to less than  $\frac{1}{100}$ " in thickness, can be removed by a lathe.

The sheets are then vulcanized by passing through a 2½ per cent solution of sulphur chloride ( $S_2Cl_2$ ) in carbon disulphide ( $CS_2$ ), or by suspension over hot sulphur chloride, or by placing in a bath of molten sulphur.

If the high grade cut sheet rubber, described above, is not required the dry rubber is made plastic and rolled with fluted wheels. Into the worked mass the sulphur and other material, such as zinc oxide, ground old waste rubber, and various other filling materials are thoroughly mixed by rolling. The heating may be carried out in large cylinders into which live steam (and therefore under pressure) is admitted, or in a sort of press consisting of a series of hollow steam-heated plates. The best temperature is about 70° C. The rubber may then be rolled between three warm rollers,  $\odot$  with their centres above one another, into thin sheets called  $\odot$  calendered sheets.  $\odot$

If fabric is to be waterproofed it is spread successively with thin layers of rubber solution, sometimes on a roller, and then passed over a warm roller, which evaporates off the solvent.

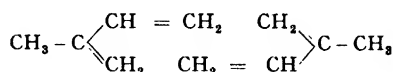
Solid tyres can be made by forcing the unvulcanized rubber through an appropriate die and jointing by solution and pressure. The tyres can then be vulcanized. Pneumatic tyres are made in a variety of ways, sometimes by squirting through an annular die and sometimes from sheet by joining. Hollow rubber articles such as balls, pneumatic tyres, etc., are prevented from collapse and sticking by the insertion of a small quantity of ammonium carbamate. This gives off gas during treatment and secures a certain inflation of the article.

Chemically, rubber is a hydrocarbon with various resinous impurities. On destructive distillation it gives, amongst other

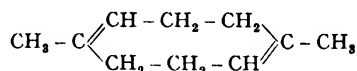
things, isoprene 
$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{C} \\ / \quad \backslash \\ \text{CH}_2 \quad \text{CH} \\ || \\ \text{CH}_3 \end{array}$$
 and various experimenters have started

with this and similar bodies and have tried to condense them

to form rubber. As a matter of fact some have been successful and substances identical with rubber have been produced—



joining up to give, probably, or possibly—



which might be regarded as the formula for rubber.

All the syntheses of rubber that have yet been accomplished, or appear at all likely, result, or would result, in a product more expensive than the present cost of the natural product. Rubber-like substances are, however, produced on a very large scale by the action of  $\text{S}_2\text{Cl}_2$ , or sulphur, or various vegetable oils, *e.g.* colza and corn oils. As a rule, however, they only resemble rubber in some characteristics and can only be used as adulterants, in the mixing stage, in natural rubber. Pigments are often introduced in the mixing stage, *e.g.* antimony sulphide gives red rubber, chromium salts give green rubber, lamp-black gives black rubber, and so on.

Rubber makes many compounds, but its sulphides are by far the most important. Ordinary rubber of commerce contains about 3 per cent of sulphur that cannot be removed by solvents and is therefore regarded as combined sulphur. When the sulphur content is greatly increased, *i.e.* up to 30 per cent of sulphur insoluble in solvents which dissolve sulphur, rubber is greatly changed in character and becomes a hard substance capable of taking a high polish. It is still a good insulator and is plastic when warm, returning to its hard brittle state on cooling. These substances form the well-known ebonite and vulcanite. They are almost unacted upon by water, alkalis, and acids, and find a very large number of applications, *e.g.* insulators, tooth plates, fountain pens, developer dishes, etc.

**CAMPHORS.**—Camphors are oxy-hydrocarbons obtained from the wood of various trees and now, also, made in the factory. The original camphor of European commerce is obtained from the camphor laurel of Formosa and Japan, although Borneo camphor

(borneol) from the *Dryobalanops aromatica* of Borneo and Sumatra was probably an article of trade in the East from very early times.

Other important camphors are menthol and thymol, although the latter might justly be regarded as a phenol and classed with that substance and cresol, etc.

The camphor industry of Formosa and Japan is a monopoly of the Japanese Government, which controls 95 per cent of the world's supply. The trees are cut down and the wood chipped. The chips are steamed in stills and the camphor, which is steam volatile, passes over with the steam and condenses. The crude camphor can be purified by centrifugalization or by sublimation in a current of hot air in iron retorts. Ultimate refining, if practised, is carried out in glass retorts on almost a laboratory scale. The yield of camphor from wood varies from 2.4 per cent in summer to 3 per cent in winter (Thorpe). Camphor is used to a slight extent in medicine but has not the vogue which it had formerly. Its chief use is in the manufacture of celluloid.

Camphor is made on a fairly large scale by the oxidation of pinene, which forms about 70 per cent of ordinary turpentine. Pinene is converted into its hydrochloride by hydrogen chloride gas, the elimination of which gives a product, camphene, that on oxidation gives camphor either directly or indirectly. Turpentine is, however, very dear, and it seems likely that natural camphor will form the chief source of supply for some time to come.

**CELLULOID.**—The most important use of camphor at the present time is in the manufacture of xylonite, or celluloid, and most people can detect the smell of camphor in celluloid, particularly when it is warm.

The preparation of celluloid (which is a U.S.A. patented name), or xylonite, or parkesite as it used to be called, is mainly carried on in America, although the substance and process were originally English inventions. It consists of obtaining pure nitrocelluloses lower than cellulose trinitrate (which is guncotton), and dissolving them in a solution of camphor in a volatile liquid solvent so that when the liquid solvent evaporates off the nitrocellulose shall remain dissolved in the solid camphor.

The nitrocellulose is prepared by treating tissue-paper (sometimes white cotton) with nitric and sulphuric acids (mixed) with less



nitric than would secure the formation of guncotton (which is insoluble in a solution of camphor in alcohol). The nitration proceeds at a temperature little above that of a warm day, but the temperature is slightly increased as the acid mixture gets diluted by the water formed in the reaction. At the end of half an hour or so the nitrated cellulose is removed and pressed comparatively free from acid. The residue of acid is removed by breaking up the pressed cake and thoroughly washing with water. The nitro-cellulose is then bleached white (with an oxygen bleach), rewashed, and dried in a filter press.

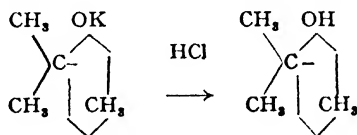
The pure nitrocellulose thus produced is again broken and the pieces mixed with thin slices of camphor and, if a coloured celluloid is required, a dye. Sometimes, too, at this stage powdered or fibrous non-inflammable substances, such as asbestos, are introduced to lessen the inflammability of the resultant celluloid. The mixture is then put into boxes in layers and each layer soaked with the solvent. This is usually alcohol, but experiments have been carried out with other solvents usually with the idea of getting into solution some substance which shall render the celluloid non-inflammable. When the mixture is pasty it is worked with warm rollers, somewhat similarly to compounded rubber in the mixing stage and with the same purpose, *i.e.* to secure homogeneity. Sheets are cut from the kneaded mass which are forced into a solid block under pressure. The removal of the solvent is a very long operation, many weeks being necessary, and it is in this part of the process that there is much room for improvement. Not only would time be saved, but less volatile solvents would be enabled to be used, and with them the introduction of ingredients, rendering the celluloid resistant to fire, might become very much easier.

Celluloid can be moulded and welded when hot. When cold it can be turned and tooled, and it is very elastic. It can also be very easily cemented to itself or other substances by means of solutions of nitrocellulose in various solvents, and in particular in amyl acetate. This latter solution has further use in forming a covering for bronze, silver, nickel, etc., which is unaffected by the atmosphere. It is also used to make the fabric of aeroplane wings and balloons airproof and gas proof. It is known as celluloid varnish and dope.

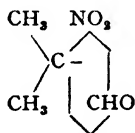
The uses of celluloid itself are too well known to need enumeration : they include material for knife handles, piano keys, serviette rings, decoration for Christmas cards, combs, brush backs, etc.

**MENTHOL.**—Menthol, or peppermint camphor, is found in the English plant *Mentha piperata*, but the chief source is from the *Mentha arvensis* of Japan. The plants are macerated whilst still green and then distilled. The distillate contains oil of peppermint, and this oil, when allowed to stand, deposits long crystals of menthol. Menthol crystals melt at  $42^{\circ}$  C., are volatile, and smell of peppermint combined with a characteristic odour (menthol). They are usually sticky and produce a cooling effect on the skin and tissues. For this latter property menthol has been used as a mild local anaesthetic (especially in dentistry) and it is in popular demand, in the form of pastilles, for inflammatory affections of the throat and nose. It is also put up in the form of a snuff. When acted upon by certain chemical reagents menthol yields derivatives identical with those obtained from camphor.

**THYMOL.**—Thymol is properly a phenol, but chemically shows also marked relationships with the group of which camphor is a member. It occurs in oil of thyme (*Thymus vulgaris*) and other oils. The oils can be obtained by distillation, and when shaken with potassium hydroxide the potassium salt of thymol is produced. After filtration the thymol can be set free with hydrochloric acid and extracted with solvents or filtered off and steam distilled—



Thymol is prepared artificially on the commercial scale from an intermediate product called nitro-cuminaldehyde—



and also from a derivative of menthol.

Thymol is a useful and efficient antiseptic with a pleasant refreshing smell. It is almost insoluble in water but soluble in

alcohol. It melts at 44° C. It is used in surgery, in tooth pastes, and a preparation of it containing thymol, alcohol, and glycerine, is extremely useful in catarrh, etc., of the throat and nose (glycothymoline, compound glycerol of thymol).

**TURPENTINE.**—Turpentine is produced in North America, Russia, Finland, France, Italy, and India, by incisions in the bark of various coniferous trees (*Pinus palustris*, *Pinus sylvestris*, *Pinus pinaster*, etc.). The liquid which exudes is collected either in cavities cut in the wood of the tree itself (boxing) or else, and better, in tins fixed to the bark. The crude turpentine is steam-distilled, whereby the turpentine (top layer) and water (bottom layer) collect in the receiver. The top layer is withdrawn and dried.

Turpentine is a drying substance, *i.e.* it combines with oxygen from the air or other substances to form a solid. It is not an oil in the sense that linseed or olive oils are oils, since it does not saponify with alkaline, nor is it a paraffin hydrocarbon like kerosene. It is, however, a mixture of unsaturated hydrocarbons, the most plentiful of which is pinene. Practically all the hydrocarbons present are  $C_{10}H_{16}$ , and they differ mainly only in their effect upon polarized light. The turpentines from different pines also vary chiefly in regard to this latter property, but Russian oil of turpentine does not dry so well as the others.

Turpentine is used in the preparation of paints and varnishes since it dissolves gums, rosin, etc., and “dries.” It is used medicinally in liniments and, to a small extent, internally, where, however, it is apt to give rise to hoematuria. It is used in the preparation of artificial camphor, and if it could be cheapened no doubt would find very much extended use in this direction.

It is interesting to notice that the turpentine industry of France has been the result of artificial creation. Pines yielding turpentine (chiefly *Pinus pinaster*) were planted to prevent the landward march of the dunes, in the Landes, and to reclaim wastes already formed. The experiment has been quite a success, and similar operations elsewhere may have an important result in effecting a much needed increase in the yield of turpentine.

**ROSIN.**—The solid residue from the steam distillation of crude turpentine is rosin or colophony. All rosins are glassy in fracture

but they vary in colour from very pale yellow (from the first turpentine yielded from a tapping) through darker yellows to the dark brown of the rosin which continues to exude after all the more liquid turpentine has ceased to flow.

Rosin has very many, comparatively small, uses : for a flux in soldering, for core gum in foundry work, in the manufacture of varnishes and sealing wax, and for caulking ships. It is also used in the paper industry, for candles, for violin bows, and, since it saponifies with alkali, in making soap. Rosin is sometimes distilled with the production of spirit and rosin oil, which are used in varnish and in lubricants. Sealing waxes are made by mixing rosin, shellac and turpentine to a paste with a pigment added. The wax for sealing bottles is made from rosin and beeswax melted together with colouring matter.

**Gamboge** is a special rosin which exudes from an East Indian and Cambodian tree (*Garcinia morella* or *Garcinia cambogia*) after tapping. It is collected in bamboo receivers and used medicinally and in the preparation of the well-known water colour.

**GUMS.**—There are a very large number of other substances resembling rosin obtained from special sources and used for special purposes.

**Gum arabic** is one of the most important. It is an exudation from thorny acacias growing in the scrub lands of Upper Egypt and Arabia, probably developed to render the plants unsavoury to animals, and therefore to assist them in their very hard struggle for existence.

**Gum senegal** is similar to gum arabic and comes from similar plants, in a similar region, to the north of the Western Sudan.

**Gum dammar** and **gum benzoin** are obtained from Sumatra and south-eastern Asia.

**Agar-agar** is a gelatine obtained by boiling up seaweeds from the same area.

**Asafoetida** is a gum obtained from the roots of plants of a species of "ferula," and especially *Scorodosma foetidum*. It grows in Afghanistan, the Punjab, and Persia, and the gum should be extracted from the living roots. It is an important tonic and anti-flatulent. It is only when it begins to decompose that it develops the unpleasant smell which has given rise to its name.

**The Copals** are hard varnish gums which have already been considered (Kauri gum, Zanzibar copal).

**Shellac** develops on certain Indian and East Indian trees (*Ficus indica*, *Butea frondosa*, etc.), after attack by an insect (*coccus lacca*) into the composition of whose cocoon shellac enters. The cocoons (stick lac) are gathered and purified by melting and working in boiling water. A red colouring matter is extracted, as from cochineal, and was formerly an important dye known as red lac. The purified and molten gum (seed lac) is poured on to cold metal plates where it solidifies in sheets, which are the shellac of commerce. Shellac is soluble in alcohol, and such solution is a very fine quality varnish. It is also used in making hats, paper size, etc.

## CHAPTER XXIII

### OILS AND FATS

**OILS AND FATS.**—The oils dealt with in this chapter will be such as are esters, that is to say, those which are compounds of an alcohol with an acid and are decomposable by alkalies into soap-like substances and an alcohol. This alcohol is almost invariably glycerine, and therefore practically all the natural oils (and fats) are triglycerides.

Fats are merely oils which are solid at ordinary temperatures. Where the alcohol on saponification is not glycerine the natural body is usually termed an essential oil.

There are a very large number of natural triglycerides and many classifications are possible, but the one quoted in Thorpe's *Dictionary of Applied Chemistry* from the *Bulletin de la Société chimique de France*, is probably the best. It is as follows—

#### I. VEGETABLE OILS AND FATS.

##### (A)—Vegetable oils—

1. Drying oils.
2. Semi-drying oils—
  - (a) Cotton-seed oil group.
  - (b) Rape oil group.
3. Non-drying oils—
  - (a) Almond oil group.
  - (b) Olive oil group.
  - (c) Castor oil group.

##### (B)—Vegetable fats—

1. Chaulmoogra oil group.
2. Laurel oil group.
3. Palm oil group.
4. Myristica group.
5. Cacao butter group.
6. Coconut oil group.
7. Dika fat group.

## II. ANIMAL OILS AND FATS.

## (A) Animal oils—

1. Marine animal oils—
  - (a) Fish oils.
  - (b) Liver oils.
  - (c) Blubber oils.
2. Terrestrial animal oils—
  - (a) Semi-drying oils.
  - (b) Non-drying oils.

## (B) Animal fats—

1. Drying fats.
2. Semi-drying fats.
3. Non-drying fats—
  - (a) Body fats.
  - (b) Milk fats.

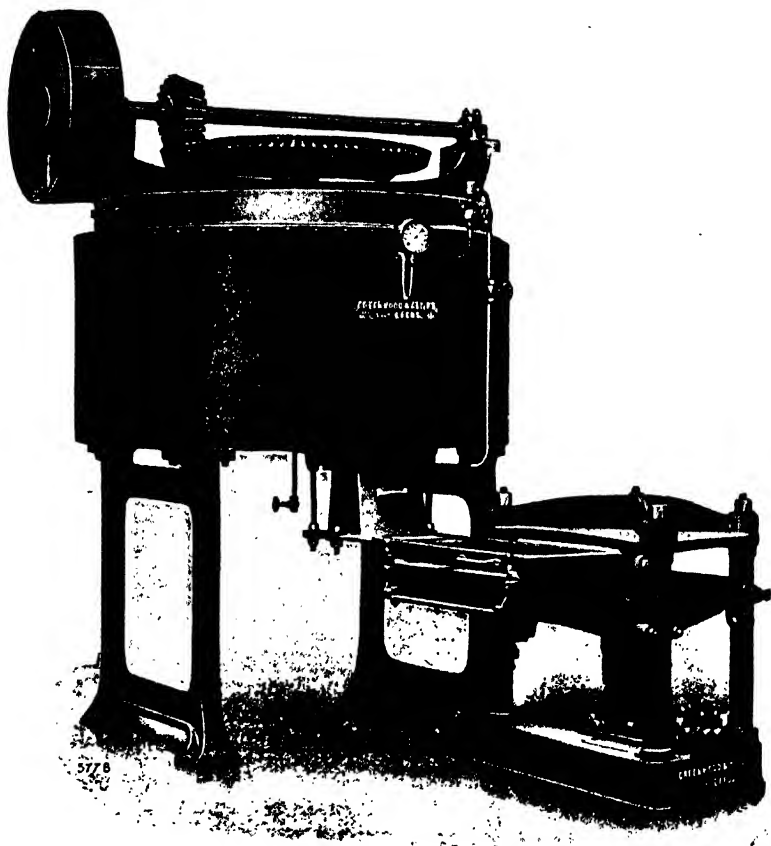
Some of the more important oils and fats will presently be considered in the above order.

**Extraction of Vegetable Oils and Fats from small Seeds.**—This is done in one of two ways, according to the nature of the seed and oil. They are “expression” and “extraction,” *i.e.* solution. Now, solution properly carried out will remove every trace of the oil and fat, and therefore whilst obviously suited to cases where very valuable oils are being obtained, is quite unsuitable in those cases where the residue, “cake,” is to be used for cattle food. In the latter case compression, which leaves a cake containing from 5–10 per cent fat, is a much better process.

The seeds are first freed from dust and grit by mechanical shaking and sifting. The shells, etc., are then removed and the seeds rolled to a coarse meal and then crushed in powerful hydraulic presses up to 300 atmospheres pressure. The oil so expressed is called cold drawn, or virgin oil, and is considerably less in quantity than the full yield, but on the other hand, since it has not been heated with other material in the seeds will therefore not have dissolved out much impurity. Cold pressing is only carried out for edible oils.

The cake from the cold drawn process is broken up and then compressed again, but in a steam-jacketed press, and even sometimes a third time at a higher temperature. Where the cake is

not required the seeds may be ground and then boiled up with suitable organic solvents, which usually boil below  $120^{\circ}\text{C}$ . These



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SEED HEATING KETTLE AND HYDRAULIC CAKE-MOULDING MACHINE

include petroleum-ether, ligroin, gasolene, etc., and carbon disulphide. There is an increasing tendency to use difficultly inflammable solvents, such as carbon tetra-chloride, but these are all, at present, very expensive.

In certain cases fruits are first expressed and then extracted, *e.g.* olives.



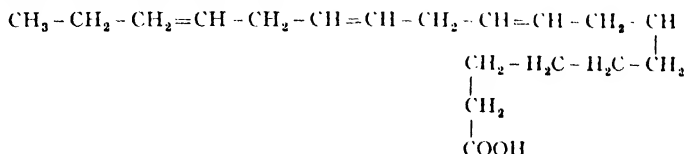
**Animal Oils** are usually obtained by boiling out the well cut-up fatty tissues with water either at or above 100° C. Since water at high temperatures can, to a certain extent, saponify oils and thereby produce acids, lard and other edible fats must be boiled out at as low a temperature as possible. The fats form a top layer on the surface of the water and can be drawn off. The residue, "greaves," can then be compressed in hydraulic presses for a further supply of oil.

The crude oils obtained by any of the foregoing processes may be fit for use, but further treatment may be necessary, such as the removal of acids by steam volatilization (coco-nut oil) or filtration in presses and through fuller's earth or other absorbent substance. Non-edible oils may be purified by sulphuric acid, alkali, or oxygen (from suitable substances), but considerable risk of rancidity, etc., attends the use of such substances.

Oils are very apt to contain solid fats and acids in solution, and this is often a disadvantage. For instance, ordinary olive oil is difficult to use as salad oil if it be semi-solid. Such oils are often refrigerated immediately after their preliminary purification and the solid matter filtered off. The clear filtrate oils are sold as "winter oils" or "demargarinated oils."

**THE DRYING OF OILS.**—Oils dry because of their absorption of oxygen from the air, or in certain cases (paints) by the absorption of oxygen from oxygenated substances (dryers) which are mixed with them. Generally speaking, it may be said that the more unsaturated the oil the quicker it will dry. The term "unsaturated" in this connection does not apply to absorptive capacity but is used with reference to the state of certain of the carbon atoms in the oil. Carbon, it will be remembered, is tetravalent, *i.e.* one atom of carbon can join on to four separate atoms or groups, and where this is the case the resultant body is relatively stable. Sometimes, however, although a carbon atom can be joined to four separate atoms or groups, it only attaches itself to three, or even two. In such cases the carbon is regarded as attached to one or other of the groups by two or three links, and to be therefore in a state of strain or "unsaturated." A reactive grouping offered to the carbon in such a condition will often suffice to secure a rearrangement whereby the carbon assumes its normal state of attachment to four separate groups.

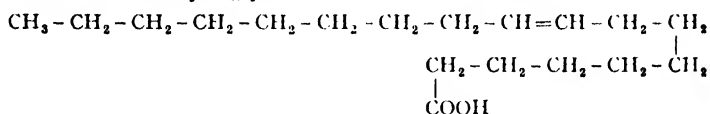
Oxygen is, of course, very reactive and is likely, therefore, to combine with all unsaturated substances, oil included. The more unsaturated groups the molecule contains the more reactive it is and the more quickly it dries, thus linseed oil is largely the triglyceride of linolenic acid—



The “ = ” denote double bonds, and it will be seen that each molecule of linolenic acid possesses three of them, and each molecule of glyceryl trilinolenate nine. It would therefore be expected that linseed oil would be a good drying oil, and this is of course true.

Cotton seed oil contains a glyceride of linolic acid, and this has two double bonds to the molecule or six to the molecule of fat. It therefore does not dry so easily as linseed oil, though it does dry to a certain extent, and is called a semi-drying oil only.

Olive oil is chiefly a glyceride of oleic acid, which is—



containing only one double bond and not drying at all.

The lubricating properties of oils can be increased by blowing air through them. The resultant products are sold under the name of blown oils, and they have increased density and viscosity. Castor oil is one of the densest of oils and is insoluble in ligroin, etc. These blown oils are soluble in ligroin, but since in density they resemble castor oil they are sometimes called "soluble castor oils."

**Boiled Oils.**—Drying oils, and especially linseed oil, are largely used because of their drying property. Drying, however, under ordinary circumstances takes a very long time and artificial means have been discovered in order to accelerate the process. The method chiefly employed is by heating the oil up to 120° C. with a small quantity of an oxygenated body, which is kept intimately mixed with the oil. Peroxides, polyoxides, or even oxygen itself may be used. The oils so treated absorb oxygen from the air much more

readily and the drier added appears to act as a catalyst, *i.e.* it enables the oil to add oxygen, perhaps by passing it on, without itself undergoing permanent change. Boiled oils are largely used in the making of paints.

**Sulphonated and Vulcanized Oils.**—When castor oil is treated at a comparatively low temperature with strong sulphuric acid a new oil is produced which confers on cotton fabric which is soaked in it the property of dyeing with certain dyes, *e.g.* lakes, to a more lustrous colour. The oil is therefore called Turkey red oil, since Turkey red is one of the most important alizarin, or lake dyes. Turkey red oil is sometimes prepared from other oils than castor oil, *e.g.* cotton seed oil.

Oils absorb sulphur similarly to rubber and the bodies produced, called vulcanized oils, are used as adulterants in the compounding stage in the preparation of rubber.

Sulphur chloride ( $S_2Cl_2$ ) reacts in the cold and produces an uncharred white crumbly substance known as "white" (rubber) substitute. Sulphur only reacts on heating (to about  $160^\circ$ ) with the oil and a "brown" substitute results. Corn oil (maize oil), rape oil, soya bean oil, and castor oil are the oils chiefly used.

Nitric acid reacts with oils, producing bodies which unite with nitro-celluloses (see under Celluloid), giving substances soluble in acetone, etc. The solution is used (amongst other purposes) for enamelling leather.

**DRYING VEGETABLE OILS. Linseed Oil.**—Linseed oil is prepared, as previously described, from the seed of the flax, which is grown chiefly in Argentina, U.S.A., Russia, and India. The resultant cake is valuable as a cattle food. Up to 40 per cent of the seed consists of linseed oil, but all of this is not extracted by the "cold drawn" process which, of course, yields the purest oil. The oil may be purified by strong sulphuric acid, which gives a charry precipitate containing most of the impurity. When the oil is to be used by artists it is sun-bleached.

Linseed oil is used for paints and in the manufacture of soft soap and linoleum.

In the manufacture of linoleum a length of coarse cotton is hung from the top of a high building kept to a temperature of about  $37^\circ C$ . Linseed oil is allowed to flow from the top over the fabric

(scrim) and is re-pumped to the top when not absorbed. A continuous circulation of oil is thus maintained which dries on the fabric on absorption of oxygen from the air. The oil may be oxidized by boiling with red lead or a similar body and whilst still hot spraying into air. The oxidized dry oil is then ground up with cork dust and, if necessary, a pigment. It is made to a paste with boiled oil and spread on strong canvas. When dry it can be printed or a mosaic of different colours made.

After prolonged boiling linseed oil becomes very thick and forms the vehicle in printers' ink. Sometimes in making printers' ink the oil is actually burned until it acquires the required consistency.

**Soya Bean Oil.**—Soya bean oil is obtained from the seeds of *Glycine soya*, which grows in Manchuria, China, Japan, and South-Eastern Asia generally, whilst it will probably become a successful crop in North and South America, Australia, Africa, and Europe, after the present experimental stages have been carried to success. The cake is a very valuable cattle food, especially for dairy cows. The oil is used for rubber substitute, soft soap, lamp oil, etc., and as an adulterant for linseed oil. Soya bean oil is not as popular now as it was a few years ago.

Poppy-seed oil is obtained from the seeds of *Papaver album* and *Papaver nigrum*, cultivated in Europe, Asia Minor, Persia, India, China, and Manchuria. The seeds contain up to 50 per cent oil. The oil is prepared in the usual way and the cold drawn oil is largely used as a salad oil and for pictorial art.

Other important vegetable drying oils are tung oil, hemp seed oil, and sunflower seed oil.

**SEMI-DRYING VEGETABLE OILS.** **Corn and Maize Oil** is made from the non-starchy germ in the grain of Indian corn or maize. The grain is first allowed to sprout, as in the preparation of malt from barley. It is then made into a mash with water and the starchy matter strained off. The germs so produced are dried and then expressed in the usual way. A yield of about 40 per cent, by weight of the germ, is obtained. Corn oil is used for salad oil, in making soft soap, margarine, vegetable lard, and rubber substitute.

**Cotton Seed Oil.**—After the cotton bolls are picked the fibre is "ginned" out and the seeds remain. These are usually exported to England or treated in the United States. Sometimes the outer

covering of the seeds is removed before expression (American seed) whereas other (*e.g.* Egyptian) seed need not be. The expressed oil, which varies in colour according to the time the seeds are kept before manufacture, is used as a salad oil, for margarine, for lard substitute, and for soap. For winter use on the table it is demargarinated, *i.e.* the stearin is precipitated by refrigeration and filtered off.

Cotton seed oil is largely blown and the product used as a lubricating oil after admixture with other lubricants. The world production of cotton seed oil exceeds 1,000,000 tons per annum.

**Sesamé Oil.**—Sesamé oil is obtained from the seeds of *Sesamum indicum*, which is grown in India and monsoon Asia generally, the Levant, in Egypt, and in tropical and temperate Africa, both north and south of the Equator. In America also sesamé is grown, and in Brazil, Venezuela, Mexico, and the West Indies.

Sesamé oil is of varying grades according to the mode of expression and origin of the seed. The best oil is used in margarine and the presence of some sesamé oil in margarine has been enforced by law in some countries, *e.g.* Belgium. Lower grade oils are used for soap, burning oil, and for the preparation of rubber substitute. The cake is very rich in oil and is used to bring low grade cakes up to the requisite oil content.

**Rape Oil.**—Rape seed, or colza, oil is obtained from the seeds of rape (*Brassica napus* and *Brassica campestris*). Rape is sometimes grown in England as a sheep fodder, but in most other European countries and in India it is grown for the seed. The seed is either expressed or extracted by carbon disulphide or low-boiling paraffins, and is purer when extracted, but the residue is then useless as a cattle food. It is, however, of value as a manure. The crude oil is refined by charring the impurities with strong sulphuric acid. Although colza oil is used for foods yet its chief uses are as a burning oil and as a lubricant. As a lubricating oil it can be used either in its refined state or blown. Rape oil is also used for "quenching" hot iron.

**Almond Oil or Oil of Almonds** (Oil of sweet almonds).—Oil of sweet almonds is in practice almost invariably prepared from bitter almonds (*Prunus amygdalus amara*) because, after expression of the sweet oil, the cake can be treated in order to obtain oil of bitter

almonds or benzaldehyde. Bitter almonds yield about 40 per cent of sweet oil of almonds.

Oil of almonds is chiefly used in medicine, in particular as a hair tonic and in affections of the ear. Oil of almonds is very similar to, and often adulterated with, peach and apricot kernel oils.

**Arachis Oil** (Ground nut oil).—Arachis oil is obtained from the familiar arachis nuts (monkey nuts, pea nuts, ground nuts) which are the seeds of *Arachis hypogaea*, a plant cultivated in monsoon Asia, Argentine, Mediterranean Europe and Africa, West Africa, U.S.A., and West Indies. The nuts are shelled by machinery and the inner red-brown skin blown off (if necessary). The oil is expressed in two or three stages, the first or cold drawn oil being, as usual, the best.

This oil is demargarinated for use as a salad oil, and is also used in the manufacture of margarine. This grade of arachis oil is frequently used with, or instead of, olive oil. The low grade oils are used on a large scale in the manufacture of soap and also in lubricating oils.

**Olive Oil.**—Olive oil is present in the fruit and stone of the olive (*olea europæa*). The olive tree is grown in groves in the Mediterranean area, and to a very small extent in Mexico and California. The olive is a typical Mediterranean product, *i.e.* it does its growing during a short winter-spring wet season and spends all the dry summer in ripening. The dry Mediterranean summer is adverse to the growth of good grass, and therefore milk and butter are scarce, and it is the olive which is the principal substitute for them. The Bible contains many examples which show the importance of oil (olive oil) in the Mediterranean area. Although the olive tree is cultivated in all Mediterranean countries, yet the oil is not uniform in quality. The best comes from the south of France (Provence oil) and Tuscany (Lucca oil).

The best oil is obtained from the pulp of the barely ripe fruit, which is hand-picked and subjected to very gentle pressure indeed. Subsequently the fruit is recompressed a second and third time, yielding an increasingly impure oil. The cake, after the third expression, still contains oil and would form a good cattle food, but olive oil is so valuable that the cake is usually treated with a

solvent (carbon disulphide) and every trace of oil removed, leaving a residue fit only for manure.

The stones are also crushed, sometimes separately and sometimes along with the fruit, and the resultant oil is olive oil, although when obtained from the stones only it is usually called olive kernel oil.

Some olive oils, *e.g.* Tunisian oil, deposit "stearin" on cooling, and they are therefore refrigerated and filtered (demargarinated) before sale.

Olive oil is used medicinally as a very mild aperient, as a salad oil, for frying, etc., for packing sardines (although in the latter case cotton seed oil is usually substituted nowadays), for best quality toilet soaps, for Turkey red oil (instead of castor oil), for lubricating oil, and for burning oil.

**Castor Oil.**—The familiar ornamental castor oil plant of the conservatory is the plant whose seeds yield castor oil. It is *ricinus communis*, and although under temperate conditions it is of shrubby habit yet in the tropics it grows into a tree 40 ft. high. *Ricinus communis* is cultivated for its seeds in the east of India, in Java, in California, and in the Mediterranean area, *e.g.* Italy. The seeds are best shelled (decorticated) before expression and, like olive oil, there may be three expressions, following which the cake is extracted with carbon disulphide (castor oil will not dissolve in light petroleum except in a 1 : 1 quantity). The cake, even if not extracted, is not used as a fodder since it contains a poisonous alkaloid (ricin). Ricin is also present in the seeds themselves, and three of them are said to constitute a lethal dose for an adult. The poison is destroyed on treatment with steam or alkali, and it is claimed that cake so treated is a non-injurious and fattening cattle food, but, at any rate in England, there is no demand for it and castor oil cake finds its chief use as a manure. Crude castor oil is purified by steaming and sun-bleaching.

Castor oil is used as a safe aperient and in the manufacture of margarine, but its chief uses are for Turkey red oil (*q.v.*) and as a lubricant for internal combustion engines.

The lubrication of the cylinders of internal combustion engines is a difficult matter, because at the high temperature of explosion some of the lubricating oil becomes volatilized and is burned along

with the petrol or benzene which forms the fuel. The air is, however, supplied in the right proportion completely to oxidize benzene or petrol, as the case may be, and is insufficient to convert all the lubricant into carbon dioxide and water. Some of this, therefore (as in faulty combustion in a stove), becomes carbon, or soot, which is deposited on the inside of the cylinder and makes working difficult, and in time, impossible. Internal combustion engines working at a high rate, *e.g.* aeroplane engines, cannot, therefore, be oiled (in the cylinders) with a hydrocarbon lubricating oil without having to be repeatedly taken down and cleaned. Castor oil, however, probably because of its rather high oxygen content, does not "carbonize" so easily and is at present the only lubricant used for aeroplane cylinders. The whole problem of lubrication is, as a matter of fact, very little understood and is one upon which great light should be thrown in the next few years.

Castor oil has been restricted in its use as a lubricant since it is insoluble in mineral oil, but it has been found that prolonged steaming under pressure gives a body which, whilst retaining the good properties of castor oil, is at the same time soluble in the paraffins and naphthenes.

When castor oil is destructively distilled oenanthylic aldehyde is one of the constituents of the distillate. This is "cognac oil," and it will be remembered is one of the substances used in the concoction of brandy from silent spirit. Castor oil is the most dense of all the common oils.

**VEGETABLE FATS. Non-drying.**—Laurel oil, which is used by veterinary surgeons, is prepared by compressing or boiling with water the berries of *laurus nobilis*. It is a green fat of the consistency of butter.

**Palm Oil.**—Palm oil is obtained from the fermented fruit of the palm tree (*eloeis guineensis*), which is cultivated in tropical West Africa, Lagos, Congo, etc. The fruit, which first forms when the trees are five or six years old, grows in bunches, which are cut down when the fruit is ripe. The separated fruits are damped with water and buried in a leaf-lined hole in the ground to ferment. After about a fortnight the pulp has sufficiently softened to permit the removal of the kernels (see Palm-kernel Oil) and is pounded up with pestle-like sticks. The macerated pulp is then placed in



a crude tank formed by a cemented hole in the ground and left while the oil runs out. This is ladled out as it collects and is the best quality oil. Further yields of inferior quality are obtained by expressing the pulp and boiling it up with water.

Palm oil varies from soft to hard according to the amount of saponification which has taken place. The true fat is quite soft at ordinary temperatures, but the rough method of treatment causes a good deal of hydrolysis to take place with consequent formation of the hard palmitic acid. The softer the oil, therefore, the higher the price it fetches. Palm oil is used chiefly in the preparation of soap and candles. It is also used to prevent oxidation of iron plates which await tinning.

**Cacao Butter** has been considered under COCOA.

**Coconut Oil.**—Coconut oil is derived from many sources, but the most important are the fruits of *cocos nucifera* and *cocos butyrace*. *Cocos nucifera* is the more important of these commercially, and enormous quantities of coconuts are produced every year, but this has already been dealt with on page 159. Suffice it to say that copra is prepared either by sun-drying the kernels, or by drying them in kilns heated by a coconut shell fire, the former being the better method. The copra so prepared, which should contain a minimum of free fatty acid, is exported to the crushing mills, where it is treated very similarly to small seeds. The oil from the first expression only is useful for margarine; the subsequent dark-coloured oil cannot as yet be bleached and is used in the manufacture of soaps, especially marine soaps.

**Palm-kernel Oil.**—Palm-kernel oil is prepared by crushing the kernels extracted from *eloeis guineensis* in the course of preparation of palm oil. It is quite different chemically from palm oil, but very closely resembles coconut oil and can always be used as a substitute for it.

**ANIMAL OILS.**—Most of the important animal oils are from marine animals and include menhaden oil, cod-liver oil, seal and whale oil (train oil). They have been previously mentioned (pages 162–3).

The most distinctive use of animal oils is in the dressing of leather, although they are used as lubricants and have very many other applications.

Neats foot oil is prepared on a vast scale in the various stock yards of the world by boiling up the feet of cattle with water. The oil, which is lighter than water, floats to the surface and is removed. Neats foot oil is one of the most important of lubricating oils.

**ANIMAL FATS.**—**Tallow** is one of the most important of fats. In its preparation the connective tissue from beef and mutton is heated by means of super-heated steam, externally applied, in large iron vessels. When pure it is colourless and almost tasteless, but it acquires a very unpleasant taste and smell on exposure to the atmosphere. Tallow was used in the manufacture of candles but is now always hydrolyzed first, the glycerine being collected and only the hard fatty acids being used for burning. Tallow is, of course, one of the most important materials in the manufacture of soap, and many lubricants contain it. Tallow is used in the preparation of oleo margarine.

**Lard.**—Lard is prepared from pig-fat similarly to tallow, and the very best is from the pure kidney fat (flare). Lard is chiefly used as an edible fat, but a valuable lubricating oil is made by compressing lard in woollen bags when lard-oil filters out. The solid residue, or cake, is material for the manufacture of candles. Pure lard containing no free fatty acid is used in the preparation of oleo margarine.

**Butter.**—Butter is a fermentation product from milk, and especially cows' milk. It differs from almost all other fats in its high proportion of glycerides of an acid of low molecular weight which makes the detection of adulterants very easy. Butter has been considered under Foods.

**MANUFACTURE OF HARD FAT.**—One of the problems in the fat industry has been that the supply of animal fat is regulated by the supply of meat and falls far short of the demand. Recently, however, processes have been discovered which succeed in producing bodies substantially the same as animal fats from unsaturated vegetable oils.

It has already been mentioned that the highly unsaturated oils are usually the drying oils, and it was known that a reduction in the amount of unsaturation would result in an increasing solidity and a permanent fattiness. The problem therefore was to convert one or more of the  $-\text{CH}=\text{CH}-$  groups in each unsaturated acid

radicle into  $-\text{CH}_2-\text{CH}_2-$  groups, whereby the glycerine stearates might result. The oils concerned would not, however, unite with hydrogen even when freshly produced in a solution of them (nascent hydrogen), and it was not until a further discovery was made that the operation became commercially possible. It was discovered that many bodies which would not normally combine with hydrogen would do so when passed with it over very finely divided platinum, palladium, or nickel, and research following this line showed that if an unsaturated inedible oil were briskly shaken with extremely finely divided nickel at a temperature of just less than  $200^\circ \text{C}$ . and hydrogen gas were present in bulk, *e.g.* under pressure, that the  $-\text{CH}=\text{CH}-$  groups would be reduced to  $-\text{CH}_2-\text{CH}_2-$  and fats identical with tallow and lard produced. This is now carried out on a very large scale in the preparation of edible fats for use in the preparation of margarine and for culinary purposes, and also for the manufacture of hard soaps which only result from hard fats.

**Sources of Supply.**—The sources of vegetable fats available are —

COPRA.—From Dutch East Indies, India and Ceylon, Philippines.

PALM KERNELS.—90 per cent from British West Africa.

GROUND NUTS.—From India and French West Africa.

COTTON SEEDS.—The export of cotton seeds is very variable according to the price, and the price varies according to the supply of other oils, and this is true of nearly all other vegetable oils. A shortage of one leads to a demand for another with a consequent increase in price. The increased price decides that oil seeds which might have been retained for home use are exported and inferior substitutes used at home.

The chief sources of supply are Egypt and India; the U.S.A. retaining all her yield.

LINSEED.—Supplies are obtained from Argentina and India. The U.S.A. retains not only her own crop but also that of Canada

**TESTING OF OILS.**—Oils of all expensive kinds are in commerce very heavily adulterated, and the detection of adulteration is an important operation in the industry. The most important characteristics are the density, the refractivity, *i.e.* the amount they

deviate the path of a ray of light passed through them ; the quantity and kind of fatty acid yielded on hydrolysis and especially the iodine number, which is in proportion to the amount of iodine absorbed by a molecule of the fat, and hence is a measure of its unsaturation. This furnishes a key to the acid present.

## CHAPTER XXIV

### LEATHER AND TANNING MATERIALS

**LEATHER.**—The skins of animals consist of two main layers, the outer skin or epidermis, which consist of hard flattened cells; and an inner layer of soft spherical cells, which is usually called the corium or mucous layer. The manufacture of leather consists essentially in converting the corium into a hard workable non-putrefiable substance.

The hair grows in the epidermis but generally from an epidermic lining to hollows in the corium. Thus mechanical scraping to remove the epidermis will not remove the hair as well and other means have to be adopted. The best and perhaps the least frequent of these methods is by hanging up the hides in a warm moist atmosphere to commence fermentation. The epidermis is most affected and after a time the whole layer, including the hair, can be removed by mechanical scraping.

The more frequent method is, however, a thorough soaking in a solution of calcium sulphide, or sodium sulphide, or in milk of lime. These, in periods up to three weeks, render the hair removable by scraping and at the same time beneficially affect the corium.

Before, however, either of the depilatory processes can be carried out the hides must have a preliminary treatment.

The great sources of hides, of course, are the stock yards of the world, and much leather is made on or near them, especially in the United States. In such cases the hides arrive at the tannery green, *i.e.* unpreserved, and they merely need careful cleaning before they are ready to be depilated. In the case of Australasian, South African, and Argentinian skins, however, which are mostly exported, they must be preserved, usually by salting and drying. These dried hides must be soaked for some time before the operation previously described can be commenced.

After the hair has been removed the finest parts of the hide, *e.g.* the back and sides (butts and bends) are ready for tanning, but the remaining parts, neck, belly, etc., and all parts required for soft leather, have to be softened before they can be tanned. This is done by inducing fermentation and infusions of fowl or

pigeon dung (for thick skins) and dog dung (for thin skins) are usually employed. Substances<sup>1</sup> are now on the market, however, which render the employment of the above very unpleasant means unnecessary, although curiously enough they are still persisted in.

**TANNING MATERIALS.**—If a solution of tannic acid be added to a solution of gelatine the gelatine is precipitated out of solution as a white insoluble mass. Gelatine is present in the hides and its precipitation, according to the above process, is at least an important part, if not the essential part, of the operation of tanning.

Tannin is to plants what albumen is to animals and most plants contain it, but tannin from some sources is much better suited for tanning purposes than that from others. The tannin is not usually given in the form of a pre-prepared infusion but the whole tannin-producing mass is added.

The following are some of the chief sources of tannin—

**Oak bark** is one of the oldest of all tanning materials in use and is probably the best of all the organic agents. It is slow in action, but old tanners claim that the leather produced is all the better for that. Practically any oak bark will do.

**Valonia** is the acorn cup of certain East Mediterranean oak trees, *e.g. quercus aegilops*. When the acorns are ripe the trees are shaken, and after being left for a short time the fallen acorns are heaped up, whereby fermentation sets in and the acorn (used as fodder) falls from the cup. Valonia is often used in conjunction with oak bark and is sometimes infused before use. It is best for sole leather.

**Myrobalans** is the fruit of an Indian plant (*terminalia chebula*). It is only good for soft leathers when used in conjunction with other tannins.

**Hemlock bark** is the next most important tanning material to oak bark, and is used on a very large scale indeed in U.S.A. and Canada. It is sometimes exported as an infusion to Europe. It is the bark of the hemlock pine (*Tsuga canadensis*). It has the effect of dyeing the leather produced to a red-brown and gives the very heaviest and strongest leathers.

**Sumach** is the dried and often powdered leaves of a Sicilian bush (*Rhus coriaria*) and several allied plants. The name is also applied to the powdered tannin produced by evaporating an infusion of the

<sup>1</sup> These are cultures of tryptic enzymes.

macerated leaves. The bush is cultivated in Sicily and the leaves used are those of the youngest shoots just before flowering. Sumach is principally used to tan morocco and similar light soft leathers, but since it contains a bright yellow (flavone) dye it is also used to lighten dark tanning media.

**Mimosa bark.**—This is the bark, or an extract of the bark, of various Australian acacias. It is being used in Europe in rapidly increasing quantity, and is red in colour.

**Turwar bark** is used in India for making “Persian” leather from goat and sheep skin, but it is not itself an article of commerce.

**Gambier** is prepared from a Malaysian trailing shrub (*Uncaria gambier*). The twigs with the leaves on are infused with hot water until a syrupy liquid results, which dries to a fairly solid paste. Gambier is used in conjunction with other tanning agents in the initial stage of tanning, and also as a dye. Gambier is sometimes called cutch and sometimes terra japonica.

**Quebracho** is a very good tanning material derived from an important Paraguayan and Argentinian tree (*Quebrachia lorentzii*) which furnishes as well a very hard red wood almost certainly destined to a high place in commerce. The tannin is made by infusing the chipped wood with water and is put on the market as an extract.

**INORGANIC TANNING MATERIALS.**—Alum and potassium dichromate both have the property of hardening gelatine and are used in photography for that purpose. They are salts containing respectively aluminium and chromium and have been used, alum for a long time, and chromium quite recently, for the production of leather. Chromium salts are the better and produce leathers practically unaffected by hot or cold water, and when used in conjunction with organic tanning agents can give leathers of astounding durability. The author has personal experience of thirteen months’ constant wear of such a chrome tanned sole without wearing it through, and Hendrick, in *Everyman’s Chemistry*, states that where policemen and postmen have had one boot soled with the very best oak bark tanned sole leather and the other with a partly mineral tanned leather, the latter has outlasted the former more than three times. As he states, it is difficult to understand the continued manufacture of vegetable-tanned sole leather.

**TANNING.**—Tanning is largely a surface action and, therefore, if a depilated hide were put straight away into a strong tan liquor it would be hardened rapidly at the surface, but the coat so formed would protect the inside of the skin from the action of the tanning and a leather of very poor wearing quality would result. At the start, therefore, the depilated hides are, after freeing from lime, introduced into pits containing practically spent tan liquor. They are either hand moved to ensure uniform action or, more likely,



TAN YARD

shaken in frames by mechanical rockers. The hides are changed from time to time to increasingly strong liquors and are then put into layers with bark, valonia, etc., spread over them and left covered with water for as long as six weeks at a time, when they are relayered afresh. The whole tanning operation takes from six months to as much as two years. When tanning is complete the hides are oiled and hung until partly dry. They then have the grain removed by a knife (pin) and are re-oiled and further dried. They are finally rolled between brass rollers and dried off.

Chrome tanning is carried out by soaking the hide in a solution of sodium dichromate containing some acid, when a yellow leather results. This is usually further treated with sodium sulphite and hydrochloric acid, or with a solution of hypo (sodium thio-sulphate



$\text{Na}_2\text{S}_2\text{O}_3$ ), which reduce the sodium dichromate to chromium oxide ( $\text{Cr}_2\text{O}_3$ ) which is green and insoluble.

**Dressing Leathers.**—Dressing leathers are medium soft leathers such as are used for boot uppers, etc. The hides, after “bating” with dung or enzymes are washed and then tanned with very weak liquors in vats with a rotating stirrer. They are then changed to rather strong liquors which are, however, never so concentrated as those used for sole leather at the same stage, and they, as a rule, are regarded as finished before the layering stage would be necessary.

It should be noticed that hides are often split, by machine knives, into several thicknesses after the preliminary stages of tanning have been carried out.

All leathers which require to be supple, *e.g.* belts, uppers, etc., have to be curried, *i.e.* softened by the repeated application of fats and oils. These are usually the marine oils described in a previous chapter, but inferior olive oil, etc., is sometimes used.

**SPECIAL LEATHERS.**—**Patent leather**, or enamelled leather, is made by varnishing the leather with a preparation made by boiling linseed oil with Prussian blue, often with some gum added, though an acetone solution of nitrated oil compound with nitrocellulose is sometimes used.

**Morocco leather** is made from goat skin, or the skin of the blue back seal (seal leather), or from sheep skins. The seal leather is used largely for tobacco pouches, book-bindings, etc.; sheep skin morocco, or French morocco, is really only an inferior imitation, whilst goat skin morocco is the original article.

The skins, after liming and bating, are tanned with sumach: sometimes a bag is made of the skin, which is filled with the tan liquor and immersed in a vat of sumach. The tanning takes but a very short time and the skins are then dyed, curried, and rolled. The very pronounced grain is sometimes artificially produced.

**Russia leather** is characterized by a peculiar pleasant smell due to the fact that it, if genuine, is tanned with birch bark but, unfortunately, nowadays birch bark tar oil is frequently applied to “Russia” leathers produced in other ways.

**Chamois leather**, or wash leather, has nothing to do with the chamois but is made from sheep skin. It has already been mentioned that partly tanned skins are often slit by machinery into

thin layers. If these layers come from the inside or flesh side of the skin they are called "flesh splits," whilst those coming from the outside are called "grain splits." The grain splits produce the harder and more durable leathers, whilst the flesh splits are used for soft leathers, and these are the starting material for chamois leather. With the object of removing as much as possible of the tough, cementy matter which unites the fibres the splits are very thoroughly limed. The lime is then removed and the skin worked time after time with a good unsaturated fish oil with a short draining between each oiling. The skins, when full of oil, are subsequently left and the oil decomposes with a consequent evolution of heat, the leather meantime turning the familiar yellow colour. Excess of oil is then removed as far as possible by pressure, and the oil so obtained, "degras," is used in currying other leathers. It will be noticed that the leather is not tanned in the ordinary way. When discussing formaldehyde we mentioned that it hardened gelatine, and it is supposed that in the course of fermentation of the oils some formaldehyde is produced which tans the skin. This idea has been technically tried, and quite good wash leathers produced by the direct application of formaldehyde and similar bodies.

**Kid leather** is made from kid or lamb skins, and after bating (puering) the skins are tanned with alum, olive oil, and yolk of egg, with some flour and salt added. The skins are dyed and a great deal of rolling and stretching is given so that the leather shall possess that curious inelastic flexibility which is its chief characteristic.

**Calf leather** is made from calf skins in a manner somewhat similar to the manufacture of kid, but instead of being partly alum tanned it is partly chrome tanned.

**Crown leather** is tanned with a mixture of horse fat, flour, tallow, and salt. It is largely used for belting.

**FURS.**—Skins are sometimes tanned with the hair on, and if this hair be soft and thick the resulting article is called fur. Animals develop such thick hairy coating as a protection from cold, and it becomes apparent, therefore, that the best furs will be obtained from the winter coats and in cold areas. Russia, Siberia, and Canada are the chief areas from which furs are derived, but the elevated regions of U.S.A. and South America also produce fur-bearing animals. Certain seals and sea otters breeding in cold

latitudes, *e.g.* the Pribyloff Islands, are very important. The chief animals resemble the weasel, and include ermines, marten, and sable-marten ; others are the skunk, opossum, chinchilla (from South America), coypu,<sup>1</sup> bear, wolf, fox, rabbit, beaver, etc.

Rabbit skins are one of the principal sources of fur, and there is probably more of this type on the market under such names' as seal coney, etc., than any other.

The pelts are cured by some such process as an alum bran tanning, and the skin may be nearly or entirely slit off. In the latter case felt is produced, which, of course, is much used in the manufacture of hats (especially coypu felt).

<sup>1</sup> The fur of the coypu is called "nutria."

## CHAPTER XXV

### TIMBER, WOOD PULP, AND PAPER

**TIMBER.**—Wood is one of those products which have been used by man since the very earliest times and of which the use is constantly increasing. It is perfectly true that in constructional work in recent years much of what would formerly have been wood work is now replaced by iron, but fresh uses are always being discovered for timber, and wood paving, pulping, etc., use up such vast quantities that not only is the world consumption increasing, but it is increasing at such a rate that there is at the present time a world shortage of this commodity. This does not mean that there is not sufficient timber in the world but that there is not sufficient available timber. Siberia, in particular, has vast stocks, but the transport of so bulky an article as lumber is so difficult that unless it be found exceptionally near to a good waterway or railway it would be too expensive, when placed on the market, to compete with timber from more favourable sources. The difficulty of transport is being met in an increasing degree by manufacture at the source, and thus we find that Sweden is exporting doors and frames rather than logs, and Newfoundland paper rather than pulp, etc. Such manufactured articles can, of course, much better stand the expense of transit.

The destruction of timber in easily available situations is serious, because trees take from 50 to 100 years before they are fit to be cut with profit. This necessitates scientific forestry and, too late for the present generation, this has at last been taken in hand by most of the civilized governments. In this connection might be pointed out the vast gain to mankind that would accrue if trees could be cultivated which would yield timber in, say, half the time required at present. Scientific breeding, although closely applied to animals, grains, tobacco, flowers, etc., has in the past been applied to timber trees hardly at all, but it will have to be attended to in future. The proper rearing of timber trees, according to Mendel's law, should not only give trees yielding timber at very much younger ages than at present, but timbers of every required

modification of character, such as knotlessness, greatly increased size, fire-proofness, etc., could probably be produced.

Partly because of the great time which must elapse before timber can be harvested it is, almost more than any other product, liable to damage or destruction. Whole areas of timber just ready for the axe may be completely burnt out, and there are also many dangerous insect pests and parasites. Trees are subject to many diseases, but just as scientific breeding of wheats has produced varieties immune to rust, so scientific breeding of trees should produce varieties immune to the more important diseases. Storms may cause great havoc in felling immature trees. Rabbits, by gnawing the bark, are especially dangerous to young trees.

**SYLVICULTURE.**—The cultivation of trees demands much thought at the outset because of the long time the capital must remain dormant.

The right type of tree for the latitude, altitude, humidity, exposure, soil, and drainage must be selected. When replacement or reinforcement of an already existent wood is desired planting is sometimes left to Nature, but if new ground is to be planted or a new kind of tree is desired artificial means must be used. Trees are usually grown from seed either planted in situ or in nurseries, but they are sometimes reared from cuttings, suckers, etc. If the tree to be cultivated is tender, some faster growing or hardier tree may be interplanted to protect it during the earlier years. Such trees can subsequently be removed and used as a catch crop for pit props, etc.

The selection of the trees to be felled is an important problem. There are two chief systems: one is by cutting all the trees in a certain section, say  $\frac{1}{100}$  of the reservation, and the other is to cut certain trees and leave others standing. It should be noted that after reaching a certain age trees do not give an increasingly valuable yield of timber.

The trees are always actually felled by hand, and the branches lopped off and sawn into suitable lengths for pit props, fire wood, etc. The main trunks are then floated or otherwise transported to the saw mills, where they are sawn into the required balks, planks, etc.

**PROPERTIES OF TIMBER.**—Dried wood is a durable fibrous material varying in density from less than .55 (Bass wood, Scotch

pine, etc.), to over .7 (ash, oak) and even in some cases, *e.g.* ebony, to above 1. Wood varies greatly in hardness and some otherwise desirable timbers may be almost too hard to work, *e.g.* Quebracho. Wood can usually be split along the fibres (with the grain) but must be cut across them (across the grain).

Wood is liable to shakes, or cracks, which may result from uneven drying (seasoning) or from a sudden increase in the rate of growth of the tree. The former type (heart shakes) radiate from the pith, whilst the latter (ring shakes) occur along an annual ring. Wood not carefully dried will warp, and advantage is sometimes taken of this fact by irregularly steaming or drying wood, *e.g.* in boat construction. Timber is often kiln dried at about 40–45° C. and will not then warp on keeping.

Although many kinds of timber will last for centuries, yet wood will, in course of time, decay, and especially in unfavourable circumstances. An important branch of the timber industry consists in preserving wood from putrefaction or disease.

The simplest method is that of charring the exterior of the wood, with the formation of an inert outer layer of carbon, but the method is not of much, or general, use. It is, however, valuable in preserving the ends of posts which are stuck in the wet ground.

**Burnetizing.**—This process was developed by Sir William Burnet in 1838. It consists essentially in forcing a very dilute solution of zinc chloride into the wood under a pressure of about 10 atmospheres. Zinc chloride is undoubtedly antiseptic and anti-parasitic, but it is possible that in the course of time it may get dissolved out again from the timber. This is prevented by forcing into the impregnated timber a mixture of glue and tannin, whereby the pore-ends are plugged with a leather. This is called the zinc-tannin process.

Copper sulphate, mercuric chloride, sugar and salt are all used in a manner similar to zinc chloride.

Probably, however, the most efficient, and most used, method of preserving timber is by impregnation with creosote, but it has the disadvantage of being relatively costly. The creosote oil used is a fraction from the distillation of coal tar containing not less than 10 per cent of phenols. The timber to be treated is placed in a large horizontal iron cylinder, with iron end doors, to admit the

timber. The doors are closed, the tank filled up with creosote, and pressure applied. There is a scale of creosote absorption per cubic foot which must be attained. For instance, it is generally reckoned that good building timber should contain at least 7 lb. of creosote per cubic foot.

As the process has been in use such a short time it is rather difficult to estimate its advantages, but creosoted timber resists the attacks of the sea worm far better than wood treated by any other process.

Timber can be rendered fairly fireproof by impregnation with various substances. Of these sodium tungstate solution is the most efficient, but it is expensive. Ammonium phosphate, ammonium chloride, alum, etc., are fairly frequently used.

**TIMBER TREES.**—Trees are of two main kinds, deciduous and coniferous. Roughly speaking, deciduous trees have broad leaves, are flowering, and shed their leaves in a pronounced winter season. (N.B.—Deciduous trees in the tropics are evergreen.) Coniferous trees have needle-shaped leaves, do not flower, but bear cones and are evergreen. Larches, however, shed their leaves in winter. Coniferous trees yield “soft wood” timber and deciduous trees “hard wood” timber.

**NORTH EUROPEAN TIMBER.**—Baltic timber, as this is sometimes called, can be grown in elevated positions in Southern Europe but is generally confined to the north. It is of the coniferous type and comes from Baltic and White Sea Russia, Sweden, Norway, Poland and Germany. Much of it is exported in 3 in. thick planks called “deals,” and this name has come to be applied to the kind of timber itself.

**Yellow Deal.**—Yellow deal, or Baltic redwood, is the wood of the Scotch fir (*Pinus sylvestris*) and is exported from all northern Europe except Denmark. The further north it grows the better it is. It is used on an enormous scale for work like house construction. It yields planks up to 40 ft. long, and is very durable but easily worked.

**Spruce, or Baltic Whitewood, or White Deal.**—This timber is the wood of *Picea excelsa*, which grows in the same regions as *Pinus sylvestris*. Spruce grows branches rather near the ground, so white deal is somewhat overdone with knots. The timber has

practically no smell. It is not so strong or durable as yellow deal, but is very suitable for interior constructional work. Inferior white wood is called spruce deal. Spruce is the best of all woods for pulping.

**Larch** (*Larix Europea*).—The larch is a coniferous tree which is not an evergreen. It grows very largely in north Russia and is fairly common in England. Larch wood is stronger and harder to work than yellow deal and is much used for fencing, etc. When tapped the larch yields Venice turpentine.

**Silver Fir** (*Abies pectinata*).—The silver fir grows at fairly high altitudes in Central Europe and its wood is exported to other European countries, chiefly from the Tyrol under the name of Swiss pine. The timber has fine resonating qualities and is used in musical instruments and also in toy manufacture.

**NON-EUROPEAN CONIFEROUS TIMBERS.**—White pine (*Pinus strobus*), or Weymouth pine, grows on the largest scale in North America about latitude 42°–50°. It is exported largely from Quebec, and is sometimes called Quebec pine and, in England, white pine. It is used for all constructional work, but special uses are doors, etc., and the decks of vessels.

**Sugar Pine** is grown in Oregon, Washington, and British Columbia. It sometimes attains a height of 300 ft., and its timber is exported to China and Japan.

**Longleaf Pine**, or *Pinus palustris*, is the pitchpine of European commerce, although it is not known by that name in south-eastern United States, which is its country of growth. It is the hardest of all coniferous timbers, and very heavy and close grained. It is used for the heaviest constructional work and for block-flooring, e.g. for school halls, etc. Pitch pine is exported to Europe in very large quantities.

**Shortleaf Pine** is grown in Missouri, Kansas, etc. Its timber is very similar to pitchpine.

**Cuban Pine** grows in south-eastern U.S.A. and in the West Indies. It is known in America as pitchpine, but the timber is inferior to that of the longleaf pine, which is known as pitchpine in Europe.

**Douglas Fir or Oregon Pine** is grown in Oregon and British Columbia. It reaches a height of 300 ft. and is particularly straight. The flag-staff in Kew Gardens is of Douglas fir, and is perfectly



straight and 150 ft. high. This timber is used for all constructional work and for ships' masts, etc., and can be delivered in logs up to 100 ft. in length.

**Kauri Pine** grows in large forests in New Zealand, and reference has been made to it under KAURI GUM. This timber is remarkably good. The yellow wood is silky in appearance and very close grained and capable of taking a high polish, whilst it is very free from knots. It is used for cabinet-making and the best exposed joiners' work.

**Hemlock.**—The hemlock is a very important timber tree. There are two main varieties, the Eastern hemlock (*Tsuga canadensis*) growing in south-eastern Canada and north-eastern United States, and a variety living further west called the Western hemlock (*Tsuga heterophylla*).

The timber of the Eastern hemlock is used in America for house construction on an increasing scale, whilst the Western hemlock, which is a much larger tree with a better class wood, is used for exposed work, *e.g.* on staircases. As has already been noted, hemlock bark is very largely used for tanning purposes in the United States.

**California Redwood** (*Sequoia sempervirens*) reaches the great height of 300 ft. and is much used in Western America for roofing shingles. It is not, however, exported to Europe.

**Red Cedar.**—Cedars grow in many parts of the world in latitudes which are not too high. The trees are also called junipers, and the wood from them has specially valuable properties in that it is easily cut and so is suitable for lead pencils, and that it has a fragrant smell and fine deep red colour. It is claimed that the odour is disliked by moth, etc., and cedar wood is therefore used for drawers and chests. *Cedrela odorata* (West Indian or Australian cedar) and toon (*Cedrela toona*) are the two trees which yield cigar-box wood.

**White Cedars.**—The *deodar*, which grows in vast forests on the lower Himalayas in N.W. India, is usually regarded as identical with the cedar of Lebanon. The timber is used for cabinet-making, and also locally for constructional work.

The various cypresses, which are widely distributed from western North America to the Mediterranean, and from Persia to Australia,

yield timber similar to cedar wood and which is applied to similar purposes.

**DECIDUOUS OR BROAD-LEAVED TREES. The Oak.**—There are many different varieties of oak, but the timbers all show very similar properties. The oak was one of the principal forest trees of England. Oaken timber comes from the Baltic, from the Adriatic, from the United States, and from Australia. The trees live to a very great age and yield hard and exceedingly durable timber. Oak was formerly used for all kinds of constructional work, but its great cost at the present time limits its use to cabinet-making, panelling, and exposed decorative rafters. When oak wood is treated with ammonia it assumes a very pleasing yellowish tone and is called fumed oak. A defect of oak is that it rusts iron which is embedded in it, and therefore nails and screws for use in oaken wood should be of brass or copper or zinc. Oak bark is, of course, used for tanning.

Most oak timbers are of similar quality, but that of the British oak (*Quercus robur*), indigenous to all temperate Europe and Asia, is supposed to be the best for general purposes, whilst the bog oak, since it is practically preserved whilst alive, by the salts of iron, etc., which it derives from the swamps in which it grows, is specially durable and valuable for all work where it will be much exposed to the action of water.

**Beech.**—Probably the most important British tree after the oak is the beech (*Fagus sylvatica*) which grows in vast forests in Europe (Bukovina = land of beeches), whilst another species grows freely in south Canada and north-eastern and central U.S.A. The wood is very hard and close grained, and well suited for hard wear, e.g. for tool handles and other handles, sabots and clogs, cart construction, etc. In England beech is often dwarfed and used as a hedging, whilst the beautiful tints assumed by the foliage in autumn entail the use of small branch ends for indoor floral decoration. The red-leaved copper beech is a well known decorative park tree. Beech wood, because it burns slowly, is a very good fuel.

**Hornbeam** (*Carpinus betulus*) is a British, European, and North American tree furnishing a very hard wood, and is used for agricultural implements, mallets, etc. The chief British supply comes from France.

**Sycamore** (*Acer pseudo-platanus*) grows in Europe (including the United Kingdom) and in North America. It is from the latter area that the commercial timber is obtained. The wood is particularly white and very smooth in appearance. It is very decorative and is used for musical instruments, cabinet-making, the rollers of wringers, etc.

**Maple.**—There are a number of varieties of maple, but only two varieties are of much commercial importance. These both grow in, and come from, North America. They are the sugar maple (*Acer saccharum*) and the red maple (*Acer rubrum*). Maple has a very fine decorative grain and polishes well. It is much used for flooring in workrooms, etc., and for picture frames and in furniture. The sugar maple is tapped in the spring and yields a sap which, after concentration, crystallizes to sugar. A yield up to 10 lb. of sugar per season is obtained from each tree tapped.

**Sweet Chestnut** (*Castanea sativa*) grows in southern England, but occurs in large forests in the Savoy and district, Southern Europe generally, North Africa, and North America. The timber is good and very durable. It is used for split (cleft) fencing, hop and vine poles, etc.

**Walnut** (*Juglans regia*) and American black walnut (*Juglans nigra*) grow in Eurasia and North America respectively. They both furnish a fine dark coloured cabinet-making wood.

**Lime or Linden** (*Tilia europea*) and (*Tilia americana*) are grown in Europe and Eastern North America. The latter variety furnishes the bass-wood of commerce, which is a very soft, yellow wood, much used for 3-ply boxes and cheaper furniture.

**White wood** is obtained from *Liriodendron tulipifera*, which, under the name of tulip tree, is grown for decorative purposes in England. There is a large output of timber from this tree in Canada and U.S.A. The wood is soft and easily carved. Canary wood is a variety of whitewood.

**Birch** grows all over Northern Europe and Northern North America. The bark is used for tanning, canoe making, etc., whilst the timber is made into chairs (it can be got up to look like mahogany), sabots, and many other articles.

**Elm** (*Ulmus*) grows in much the same regions as birch although not quite so far north. The chief characteristic of elm-wood is

its resistance to the action of water. It is therefore used for coffins, piles, keels of ships, and formerly for water pipes. Elm, however, does not weather well in open situations.

**Ash** (*Fraxinus*).—Varieties of this tree are distributed over all the North Temperate Zone. Its timber is particularly elastic and combines strength with ease of working. It is used almost universally for oars, and for shafts, handles of implements, and to some extent in furniture and building. A specially valuable curly-grained variety comes from Hungary.

**Cotton wood** (*Populus deltoides*) is one of the many varieties of poplar. It is well distributed throughout south-eastern North America, but is particularly in evidence in the south-eastern and Mississippi States of the U.S.A. The timber is not of good quality, being soft and light, but it is nevertheless much used in a world where all good timber is very dear. Cotton wood is much used for pulping.

**Hickory** is a North American tree which, however, might very well be grown in Britain if ever an afforestation scheme is developed in this country. There are many species of hickory, but the timber is nearly always very strong and very tough. It is used for axe handles, etc., and wheelspokes, and some species produce edible nuts, *e.g.* pecan nut and pig nut.

**Eucalyptus**.—The eucalyptuses are a group of Australian trees furnishing, as a rule, very hard red timber and exuding gum from breaks in the bark (gum trees). Some of them grow to a great height and some yield the medicinal oil of eucalyptus by infusion or distillation of the leaves.

Two species furnish timber very largely used in English towns for wood paving, *e.g.* Jarrah (*Eucalyptus marginata*) from South-West Australia and Karri. Australian timbers are likely to take a much larger place in commerce in the future than they do at present, and in particular will be put to uses which are at present the function of mahogany, *e.g.* *Eucalyptus resinifera* (red mahogany) and *Eucalyptus robusta* (swamp mahogany).

**Mahogany**.—*Swietenia mahogany*, the true mahogany, comes from tropical America and the West Indies. The quality of the timber varies according to the locality from which it is derived, that from Mexico (Tobasco) being regarded as the best, whilst

Honduras mahogany is somewhat inferior. Mahogany also comes in increasing quantity from Tropical West Africa, where it is called *Khaya* (*Khaya senegalensis*). Mahogany is the cabinet-making timber, par excellence, because of its beautiful colour and grain, although the colour is usually artificially deepened before the finished goods are put on the market. The wood takes a high polish, does not warp, is easily worked, and yet very durable. Besides its furniture-making uses, however, mahogany is very largely used in high-class interior fittings, e.g. for window work, etc., and on passenger ships.

**Teak** (*Tectona grandis*) is a tree producing an almost ideal timber. It grows in vast forests in North India, Burmah, Siam, and in Malaysia. The timber, which is a characteristic brown in colour, has a rather greasy feel. It is rather hard to work but is very durable. It does not rust iron and is used nowadays instead of oak for shipbuilding whilst, since it is one of the few timbers not attacked by the white ant, it is frequently used for furniture and construction in the tropics. Acids and alkali have little effect on it, and it is practically the only timber ever used for laboratory benches, test-tube racks, etc., and it is also employed for stair treads, piling, etc.

**Greenheart** (*Nectandra rodiaei*) or Bebeeru is a tree growing in northern South America, Central America, and especially in Guiana. It yields a very hard durable timber which is resistant to the pile worm; it is placed in the highest class, by Lloyds, for shipbuilding purposes. It is also used for fishing rods and piles. The bark has somewhat similar antipyretic properties to cinchona bark.

**Rosewood** is a cabinet-making timber coming apparently from several Brazilian trees. It is used for the best quality tables, piano cases, etc., smells of the rose when being worked, and yields a substitute for rose perfume on distillation.

**Ebony** is a tree furnishing white sap wood and black heart wood which grows principally in equatorial West Africa but also in most other tropical regions. The black heart wood alone is exported and is used for inlaying, walking sticks, etc. It is heavier than water.

**Box** (*Buxus sempervirens*) is a Eurasian south temperate tree of slow growth and small size and therefore yields a very close-grained,

hard wood. It is used for turning, rulers, protractors, and tool handles. Box wood is sometimes imitated by the so-called West Indian Boxwood coming from the Zapatero or Cogwood tree of the West Indies.

The sawdust from saw mills is used for a variety of purposes, *e.g.* for smoking bacon and for the preparation of oxalic acid.

**DESTRUCTIVE DISTILLATION OF WOOD.**—Wood, where it is abundant, is distilled somewhat similarly to coal at a gas works. There are a very large number of different plants for the purpose but all the larger ones are based on two principles, *viz.*, the economy of fuel in distillation and the rapid discharge of the solid residue (charcoal) after distillation is complete. The necessity for the former is obvious, whilst that of the latter at once becomes apparent when it is remembered that it may take more than a week for the charcoal to cool sufficiently to be transferred to the open air without risk of burning. During all that time, of course, the kiln would be out of action.

Fuel economy is effected by the pattern of the kiln and, in particular, by using the gaseous distillation products, about 38 per cent of the total distillate, and consisting chiefly of carbon dioxide but containing also some carbon monoxide and hydrocarbons, to heat the wood. These gases are sometimes converted into producer gas for heating purposes. In many plants, too, the gases from the fuel wood are also conducted right into the retorts or kilns containing the wood.

The cooling of the charcoal under conditions which allow of the immediate recharging of the kiln is usually carried out by loading the wood logs, cut into regular lengths and sections, on to iron trolleys which are run into the kiln and, immediately distillation is complete, pulling the charcoal laden cars out of the kiln and putting them into special cooling chambers until the charcoal is cool.

The market value of the charcoal depends largely upon its being in large regular pieces, and partly for that reason the distillation of sawdust and chips, *etc.*, of wood has never been a real commercial success. In the case of sawdust, too, there is some chance of explosion unless it be heated in very small quantities at a time.

The liquid distillate consists chiefly of water, tar, acetic acid, and methyl alcohol, with some acetone, *etc.* If hard wood has

been used the tar is of no commercial use, but the tar from pine wood is very valuable and is used for tarring fencing, roofs, etc. It has a yellowish colour which increases the demand for it. The distillate from pine woods contains also crude turpentine and rosin oil.

When pine wood is burned in heaps or "meilers" by charcoal burners there collects under the charcoal a mass of Stockholm or Archangel tar, which is used for the same purposes as pine wood retort tar. It is also distilled for creosote.

**Separation of the Distillate.**—The distillate is first allowed to stand when the undissolved tar collects at the top or bottom and can be removed. The liquid, called pyroligneous acid, is then neutralized with lime, which forms non-volatile soluble calcium acetate with the acetic acid. It also precipitates most of the bodies which are present only in small quantity and leaves water, methyl alcohol, and acetone as the only readily volatile substances. The liquid is distilled best by a process which allows the vapour first formed to heat the liquid in another pan and so on (Mayer Still) whereby a great saving of fuel is effected. By this means the methyl alcohol can be obtained containing very little water but a considerable quantity of acetone. If anhydrous calcium chloride be added in proper quantity it will form a solid crystalline addition product with the methyl alcohol, and the liquid acetone can then be removed. A little water serves to decompose the methyl alcohol calcium chloride compound, and a further distillation secures methyl alcohol containing only a small quantity of water which can be taken out by quick lime.

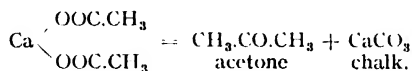
Another method of separation has been described which consists in the formation of a sodium methyl carbonate with carbon dioxide under pressure. The acetone can be filtered off and the sodium methyl carbonate distilled with the production of pure methyl alcohol.

Methyl alcohol is used for varnishes and as a solvent for other purposes. It is largely used for introducing methyl groups into dyestuffs; as a fuel; and in the preparation of formaldehyde (formalin).

The solution of calcium acetate is evaporated until it will crystallize on cooling. It is then mechanically dried and marketed. One of the most important uses of calcium acetate is for the preparation

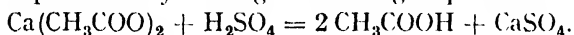
of acetone, which is a very valuable solvent and is also used in the manufacture of chloroform.

The best commercial method of obtaining acetone is to introduce steel trolleys containing up to 6 tons of calcium acetate into steel retorts and heating up to 300° C. when it is broken up according to the equation—



The cars can be removed at once at the end of the reaction and fresh laden ones introduced, thus economizing fuel. The acetone thus obtained can be purified by fractional distillation.

Calcium acetate is also the commercial source of acetic acid which is produced by heating with strong sulphuric acid in iron stills.



If sodium acetate be required the pyroligneous acid is neutralized with sodium carbonate.

**APPLICATIONS OF WOOD CELLULOSE.**—Wood consists essentially of a bundle of long fibres which are specially hardened to secure rigidity. These hard fibres are ligno-cellulose, and when properly treated yield a high percentage of cellulose.

Cellulose is a colloidal substance insoluble in all solvents except such as attack it, and is chemically a very complicated derivative of starch or sugar.

It can be obtained by taking most fibrous plant materials, treating with, say, nitro-sulphuric acids, whereby cellulose nitrates are obtained, *e.g.* gun-cotton, and then reducing and removing the nitro groups, usually by alkaline hydrosulphides. Ordinary cotton is almost pure cellulose.

During the war Germany appears to have manufactured satisfactory gun-cotton from wood cellulose after her cotton supply was stopped, and wood cellulose is also used to a certain extent in the manufacture of celluloid.

**MANUFACTURE OF WOOD PULP.**—Wood pulp can be made mechanically by grinding up wood with water. Logs are cut into 2 ft. lengths, and a ring of these is hydraulically pressed against a large vertically axled grindstone which, of course, revolves in a horizontal plane. If much water be allowed to flow over the stone



a smooth, fine even pulp results (cold ground pulp), but when the water supply is cut down to the minimum required to prevent charring the wood pulps much more easily into a coarser material (hot ground pulp).

The pulp so prepared is separated from all particles which are too coarse by being shaken in sieve-like trays or in a centrifugal machine with an inner perforated sieve allowing the passage of only the finest pulp. In this case, of course, the pulp is partially dried at the same time as in a laundry "hydro." The pulp is further dried in large hydraulic presses, in which condition it is usually shipped.

Such pulp is called "mechanical pulp," but there are other processes which are much employed. One of these is by steaming the wood or digesting it with hot water whereby the so-called brown pulp results which yields very tenacious, tough, and elastic material which can be manufactured into boxes, etc.

**Sulphite pulp.**—This is made by treating wood chips with sulphur dioxide, acid sulphites and steam under pressure for from eight hours to two days.

**Soda pulp** is made by treating the wood chips with caustic soda under pressure.

**Bleaching.**—However the pulp is obtained it must be bleached, and this is usually done by breaking the big masses of pulp up into a fresh pulp and submitting them to the action of bleaching powder. Expense, of course, can be saved by delivering the screened pulp first produced straight into the bleaching tanks, and this is often done in big works.

**MANUFACTURE OF ARTIFICIAL SILK.**—Wood pulp can be treated with an appropriate solution of nitro-sulphuric acid or other reagents and obtained in a condition from which threads similar to silk can be obtained.

Nitro-cellulose dissolved in a suitable solvent, or cellulose dissolved in zinc chloride, or a solution of cellulose in a solution of copper hydroxide in ammonia, can all be squirted through a fine orifice in a steel plate with the production of lustrous yarns. Nitro-cellulose yarns must be denitrated with ammonium sulphide to prevent explosions, and zinc chloride removed by acid.

A particularly good imitation silk is obtained by treating wood

cellulose with strong caustic soda solution and then with carbon disulphide. This ester of cellulose with xanthogenic acid passes on standing back into cellulose. The product so obtained, "viscose," compares very favourably indeed with a "weighted" silk. Many of these silk substitutes are comparable with silk when dry, but unfortunately when wet their tenacity is as a rule very much reduced. However, it returns as soon as they are dry again, and therefore given careful handling in washing imitation silks are practically as good as natural ones. Sténosé is an attempt to overcome the weak condition of artificial silks when wet by treating them with, amongst other things, formaldehyde.

**PAPER.**—The chief raw material of paper at the present time is wood pulp, and much paper is manufactured in mills near or around great consuming centres. The very high fuel consumption, however, which may reach 1 ton of coal per ton of paper produced has resulted in an increasing tendency to manufacture the paper itself where there is much available water power, and raw material, *i.e.*, wood, together. Thus we find that paper for the Amalgamated Press publications is made where the wood is grown and pulped in Newfoundland, using local water power.

In manufacture mixtures of mechanical and chemical wood pulp with rosin, size, and about 10 per cent of kaolin (china clay) are very thoroughly beaten into a homogeneous mass with water. If ordinary newspaper is desired this beaten pulp is then strained on to an endless wire gauze band and at the same time water is extracted by vacuum suction. The pulp thereby "compacts" into a thin felt-like sheet which is passed over or between a large number of warm rollers to dry it. It is afterwards surfaced in a calender and wound on to large drums.

**Papier mache** is made by mixing up in a beater a good wood pulp with a fair quantity of china clay and starch, or casein, or glue or rosin size, with some water.

**Manufacture of Paper from Linen, Cotton Rags, and Waste.**—In addition to wood pulp there are many other materials from which paper can be made. Some of the more important are linen and cotton rags and waste from the manufacture of linen and cotton, esparto-grass, hemp, manila, and jute refuse, and worn-out hemp, manila, and jute articles, and straw.

In the manufacture of paper from rags and fabric generally, the rags are first sorted into grades of which white linen and cotton goods are the best. This operation is carried out on wire sieve tables so that much foreign matter falls through, and at the same time buttons, etc., are removed. The rags are cut into small pieces and dry-cleaned by passing through a sieve-like cylinder containing spike-like beaters. The rags are then (2 or 3 tons at a time) boiled under pressure with alkaline solutions, usually caustic soda, whereby colour is destroyed and albuminous and fatty substances are removed. The soda liquor is pressed out and then more completely removed by washing with water. After this, the rags are placed in a washing and breaking machine. This consists essentially of a shallow tank containing a large roller, movable in a vertical plane, on which are many long knife blades, and there are opposed knife blades at the bottom of the tank. The roller is fixed at a distance from the fixed knives and the charge of rags and water made to circulate by the revolution of the roller. The dirty water is removed continuously by a revolving wire gauze-rimmed drum into which the foul water flows to be caught in scoops and diverted to the sink. When the rags are sufficiently clean the drum is lifted clear and the roller lowered until the moving and fixed knives almost touch. The rags which are forced between the knife blades are practically torn to pulp whilst buttons, etc., which cannot pass through are caught in grated pockets. The pulpy mass is now bleached with bleaching powder, or by the liberation of chlorine by the electrolysis of common salt placed in the pulp and water. The bleach is removed by causing the pulp and water to flow over wire mesh, and then the pulp is further disintegrated by passing through a beating machine, which is practically a washing and breaking machine without the drum-washer, and with a roller capable of being adjusted still nearer to the fixed knives. Along with the water and pulp, china clay and other filling matter, the dye and the sizing material, *e.g.* rosin and aluminium sulphate, are beaten up into a homogeneous mass.

In machine-made paper this mass is treated just like newspaper (*q.v.*) except that an additional wire-covered roller with the water mark on, in mesh, may be used. The paper is finished in calenders.

In hand-made paper the workman dips out the pulp in a

wire-bottomed wooden frame and deposits it on a piece of felt. A whole set of interleaved paper and felt is then hydraulically pressed. Such paper is always air dried.

**ESPARTO GRASS** grows wild and is cultivated in Spain and all the African Mediterranean States except Egypt. It reaches a height of about 4 ft., and when harvested can be separated into a leafy part and a more or less straw-like stem. The best esparto grass has been used for textile manufacture, especially in the production of silk-like fibres, whilst the remainder is used for paper. The material is first dry-cleaned and then boiled with much stronger alkali solution than is used for rags in what is called a "vomit" boiler. The subsequent treatment is similar to that for good machine-made paper. Esparto grass paper is in great demand for the making of books and for lithographic work generally.

**STRAW** is treated similarly to esparto grass except that still more drastic boiling is necessary.

**BROWN PAPER** is made from jute refuse, etc., whilst cardboard, etc., is made by causing a layer of pulp to flow on to felt and then squeezing out the water.

**PARCHMENT PAPER** is made by passing the unsized paper through a bath of fairly strong sulphuric acid which changes the surface into a gelatinous substance which is greaseproof.

**WATERPROOF PAPER** (Willesden paper) is made by treating the surface with an ammoniacal solution of copper hydroxide.

**BLOTTING PAPER** is made by cutting up the rags with very sharp knives whereby short fibres are produced. The resultant paper is, of course, unsized.

In general conclusion it may be said that the longer the fibres in the preparation of paper the better and stronger will be the product.

## CHAPTER XXVI

### TEXTILES

A TEXTILE is any woven material, and under this heading we can include representatives of the animal, vegetable, and mineral worlds for wool is, of course, derived from the sheep, cotton from a plant, and asbestos is a mineral.

**COTTON.**—Cotton is easily the most important of all cloth materials, and it has been important through all the ages. Nearchus, who took part in Alexander the Great's expedition to India, wrote in 327 B.C. that "There are in India trees bearing as it were, bunches of wool. The natives made linen garments of it, wearing a shirt which reached to the middle of the leg . . . and the linen made by them from this substance was finer than any other."<sup>1</sup>

The manufacture of cotton goods has persisted in India until the present time, and Calicut, which is an important outlet for the products of the Deccan, standing as it does in a gap in the Western Ghats, has conferred its name on one of the most useful of cotton fabrics, *i.e.* calico.

Cotton also appears to have been indigenous to Central, and northern South, America, where its use was well known at the time of Columbus, whilst it still grows wild in Africa.

The cotton plant is a tree or shrub belonging to the mallow family. It is a perennial which cannot stand frost, and since it also requires nearly eight months from seed time to harvest, in the first year, it stands to reason that it will not yield at all north or south of about 40° latitude, and that even much nearer to the equator than that it must be grown as an annual. This latter condition, however, is no hardship, since it has been found better and safer to grow cotton as an annual even in those tropical areas where it would yield perennially.

It follows, therefore, that cotton can be cultivated in almost

<sup>1</sup> Quoted from Freeman & Chandler *The World's Commercial Products* (Pitman).

any area which provides eight months free of frost, and, in fact, this is so, for cotton is grown in the Banat, in Italy, in Southern China and Southern Japan, in India, Persia, and Asia Minor, in Queensland, Egypt, Nigeria, Uganda, Nyassaland, Brazil, Peru, West Indies, Mexico, and the south-eastern United States. Of all these sources of supply those which most affect the world's commerce are south-eastern U.S.A., especially Texas, Egypt, and India, and of these the U.S.A. furnishes 70 per cent of all the cotton that comes on the market.

There are many varieties of cotton plant yielding different kinds of cotton. The fibre itself is found in the seed pod after flowering and is attached to the seeds.

The chief varieties are---

**Sea Island Cotton** (*Gossypium barbadense*).—This plant has yellow to red flowers and has long, up to  $2\frac{1}{2}$  in., silky fibres only attached to the seeds. This is the most valuable of all cottons and can hardly be distinguished from silk. Threads spun from it are extremely strong, but in England, at any rate, most of it is used for contract, especially Government contract, work, and very little finds its way into the shops. Sea Island cotton, as its name implies, is best grown where there is a high humidity and is cultivated chiefly in the islands and coastal districts of Florida and the adjacent states, whither it was introduced from the West Indies. It has recently been reintroduced to the West Indies from the U.S.A. and bids fair to become a staple crop in them.

**Kidney Cotton** (*Gossypium brasiliense*) is a native of Brazil, and is so called because the seeds instead of being separate as in other cottons are united together in somewhat kidney-shaped formations, three to each boll. Like Sea Island cotton this species has yellow to red flowers, and has only long fibres which can be easily and cleanly removed from the seeds; but unlike Sea Island cotton, the fibres are not silky but wiry. Kidney cotton is used chiefly with wool in "wool mixtures."

**Upland Cotton** (*Gossypium hirsutum*) is, very easily, the most cultivated of all cottons. It grows chiefly in the south-eastern United States, bears white flowers, and derives its name from the fact that the boll contains both long and short hairs. Of these the long hairs are easily removed, leaving the short ones behind

and attached to the seed. The seed therefore has a fuzzy or "hirsute" appearance.

**Egyptian Cotton** (*Gossypium peruvianum*), is an irrigation cotton of very fine qualities, and is next to Sea Island cotton in value. The fibres are shorter than in Sea Island cotton but longer than those of Upland cotton, are fine, elastic, and spin into fine, strong threads.

**Indian Cotton** (*Gossypium herbaceum*), is a yellow-flowered plant with only short and rather coarse fibres. This is grown very largely in the hinterlands of Bombay and Calicut, but is not at all popular with Lancashire spinners. It furnishes, however, very strong fabric, and it is almost certain that scientific selection and crossing would increase the length of the fibres.

**Tree Cotton.**—There is, in addition to the foregoing, a tree (*Gossypium arboreum*) which yields good long-fibred silky cotton, but it is of very little commercial importance. It grows in India and Nigeria, etc.

**CULTIVATION.**—Given the eight months of frost-free climate, cotton can grow on almost any soil, although, since it has to be very efficiently weeded, there is some risk of heavy rains removing too large a proportion of the richer top spit in which the plant grows.

The seeds are sown in drills, about 4 ft. apart between the rows, immediately there is no risk of frost, *i.e.* from the beginning of March in Texas, to the middle of May in North Carolina. The young plants are thinned to about 1 ft. apart with the hoe and begin to flower in about three months. As soon as the bolls open picking commences, usually about five months after planting, and will continue until the plants are killed by frost because they will flower and yield cotton for a period of over three months if not killed.

Although there are machine pickers on the market they are not yet entirely satisfactory, and the overwhelming bulk of cotton picking is done by hand. This, of course, necessitates a very large supply of cheap labour, and since cotton picking also demands some care, it will be seen that this operation is the most difficult from the planters' point of view, and is likely to become more so. At the present time men, women, and children are all employed

in the work, although educational legislation is likely to remove these last in the very near future. About 1 cwt. of cotton and seeds is a very fair day's work. Immediately after the cotton is picked it is ginned, *i.e.* separated from the seeds.

The machines employed either claw into the mass with saw-like wheels, whereby the seeds are released and fall to the bottom



SHIPPING COTTON AT NEW ORLEANS

whilst the "lint" is carried off by brushes, or else the lint is made to pass between two leather-surfaced rollers that keep back the seeds which are removed by a knife blade. About one-third of the boll is lint, and about two-thirds seed. The lint is then compressed, in powerful hydraulic presses, into bales of varying weight (500 lb. in U.S.A.) for transport. The seeds are, of course, worked for oil, cattle cake or sometimes for manure.



Before beginning to describe the manufacture of cotton it might be as well to say that the U.S.A., which produces 70 per cent of marketed cotton,<sup>1</sup> is manufacturing an increasing percentage of its own cotton, and thus it appears that in the future Lancashire and other manufacturing centres must look elsewhere to make up their necessary supply of raw material. The British Cotton Growers' Association has taken this matter in hand, and has developed the cotton growing industry in many parts of the British Empire. Queensland would probably be a good area, but Australia's rooted objection to coloured labour rules it out. Of the remaining areas the most promising are Nyasaland and Uganda, with, of course, other parts of East Africa, and also Nigeria, and it is likely that in due course large quantities of good cotton will be derived from these areas. As has already been indicated, an increased supply of good cotton may be obtained from India following upon selection.

**Manufacture.**—A cotton fibre can be seen under the microscope to resemble a collapsed rubber tube with an uneven wavy exterior, and it is upon this property that the special suitability of cotton for spinning, depends. The fibre is more brittle when dry than when somewhat moist, and it is partly the humid atmosphere which has made South Lancashire the greatest cotton manufacturing area in the world. Mills in dry areas have to be steamed to create the proper atmosphere.

The first operation in cotton manufacture is to reduce the baled cotton to a fluffy open, workable condition, and this is done by passing it first over heavily-spiked rollers which break it up, and then automatically through another series of spiked rollers which receive cotton of different though similar grades, work them together, and further loosen the mass. At this stage the lint still retains any impurities which were present in the bales, and these are now removed by a further automatic transference to an "opening machine" where it is rolled between fluted and perforated rollers into sheet whilst the impurities are forced through, and this operation is again repeated in a "scutching machine."

The rolled up sheet of matted cotton fibre is now ready to be

<sup>1</sup> The percentage of all cotton grown would not be so great as this since much African and Indian cotton never comes on the market.

“carded,” which operation consists essentially of combing the cotton between very small wire-toothed rollers, getting the fibres roughly parallel in the process, and bringing them together, without twisting, into a long “rope” or “sliver.”

The slivers from the carding machine may then be drawn through either a “combing” or “drawing machine.” (For fine cotton the combing is necessary, but for coarser work it is dispensed with.) There are many successive combs in one machine with progressively finer-set teeth. These combs not only straighten out the fibres to a more parallel condition, but they also reject the short hairs which are not suitable for fine spinning. Whether the slivers are combed or not, however, they must be drawn, and this operation consists in taking many slivers and drawing them out continuously into one of greater length. The drawing is effected by rollers revolving at different speeds, and the same machine usually takes sets of six slivers and draws them into ones, then takes sets of six of these and draws them into ones, and then six of these again, so that  $6 \times 6 \times 6 = 216$  slivers are represented in the final thread. This is the usual number, but for exceptionally fine work  $8 \times 8 \times 8 \times 8 = 4,096$  doublings may be made.

All this time the fibres have not been twisted at all, but by now they are ready for this operation, which is done in successive stages.

The first machine, or “slubber,” first further draws out the slivers and then delivers them on to a rotating bobbin by means of an independent rotating arm, and thus gives some twist. Two of these “slivers,” or “rovings,” as they may now be called, are drawn together through the next or “intermediate” machine, which resembles the slubber, and further twisted, and the “roving” machine then takes two of these rovings, draws them together, and twists them still more. In very fine work even this operation may be repeated (Jack frame).

The rovings are now ready for spinning into yarn. There are two main types of spinning, one “continuous” spinning, as its name implies, continuously spins the rovings into yarn, whilst the other, worked by a mule machine “intermittent”-ly, spins the rovings. The continuous or Ring spinning machine is worked by

women, but for the mule male hands are almost universally employed.

The Ring spinner first of all further draws out the thread between rollers, and then delivers it via a rotating ring on to a spool on a spindle which is rotating at a much faster rate. The thread is thus much twisted as it is wound on the spool.

A cotton mule may have as many as 1,500 spindles.

As a result of this operation a finished thread results, but these threads may be further doubled together without extension of length in a "doubling" machine and a 2, 3 or 6 cord cotton result.

Where a smooth thread is required the surface fluff is removed by "gassing," *i.e.* passing it through a Bunsen flame at such a rate as to singe off the fluff, but too quickly to burn the thread itself.

Weaving is the making of thread into cloth, and is always carried on nowadays by power looms. In a loom long special strong threads are paid out from bobbins on a rod, the weaver's beam, and crossed by other threads at right angles. The long threads are called the warp and the cross threads the weft. In the simplest kind of weaving every alternate warp thread is depressed and the others raised so as to make a "shed," and through this shed the shuttle holding the weft thread travels to return again through another shed. Each successive weft is pushed hard into place by a slye, and the cloth, as completed, is wound on to a roller. Of course in more expensive and figured work the operation is much more complicated, and very elaborate devices are used to lift or depress whole combinations of warp threads, whilst since the weft thread may, in such cases, not have to return through the warp, arrangement has to be made to get the shuttle back otherwise. The Jacquard loom, which was invented specially for the Lyons silk manufacture, is the most important of all machines for the manufacture of figured fabric. In it combinations for raising the warps are joined together to single automatically-worked levers above the machine.

It should be mentioned that the warp threads are always sized before mounting so as to secure no twisting of the spun thread and further to strengthen the warp.

**Composition.**—Cotton is practically pure cellulose (90 per cent) and water (8 per cent). The remaining 2 per cent consists of oil or wax and mineral matter, and it is because of this purity that cotton, above all other forms of cellulose, is used in the preparation of nitro-cellulose for gun-cotton, etc.

The oil seems to have the special property of rendering the fibre somewhat impervious to water, and it has to be removed by saponification with boiling dilute alkali under pressure if "absorbent cotton wool" is required.

**Mercerization.**—Mercer, in 1844, noticed that cotton when immersed in strong caustic soda solution underwent a profound change, and this has given rise to a very important branch of the cotton industry. As has already been mentioned, individual cotton fibres are twisted rough and flat, but if placed in strong soda solution and kept taut they become untwisted, smooth, and nearly cylindrical in section, *i.e.* they resemble individual silk fibres, and in actual practice they do approximate in appearance to silk very closely indeed. Not only, however, is the cotton improved in appearance, but it is also improved very greatly in tensile strength. Mercerized cotton also dyes much better than the untreated material.

The operation of mercerizing can be carried out either on the yarn, in hanks, in single threads, or in the manufactured cloth.

The best solution of caustic soda is of medium strong concentration, and the cloth, or yarn, or whole series of warp threads can be passed through continuously since there does not appear to be any improvement in quality after about a minute's immersion. The soda can then be washed off by hot water and the fibre or fabric dried by hot rollers.

**Kapok.**—There are other plants besides cotton which have fibres attached to the seeds, but in all cases these fibres are circular in section and lack the twist which is almost essential in spinning. The most important of these fibres or "flosses" as they are called, is kapok, which is obtained from the seed capsule of *Eriodendron aufractuosum*, a Javanese tree. Kapok is used chiefly in upholstery, in lifebelts (instead of cork), and in quilts.

**FLAX.**—Flax has been used as a fabric material since and during the Stone Age, whilst Egyptian mummy cloths are often of the very finest linen.

The flax plant (*Linum usitatissimum*) is cultivated in Russia, U.S.A., India, Argentina, Canada, Southern Belgium and Northern France, North-East Ireland, and to a certain extent in England (Suffolk and Wiltshire). In India, U.S.A., and Argentina, however, the crop is grown almost exclusively for the seeds (linseed) and fodder and not for the fibre.

Linseed is drilled in and the field requires careful cleaning. When the seeds are nearly, or quite, ripe the flax is hand-pulled, roots and all being taken up. There are various pulling machines, but they do not as yet appear to be so efficient as hand labour, and flax cannot, of course, be cut because much of the valuable fibre is in the lowest part of the stem. After pulling, the flax is tied into bundles (like corn only smaller) and stood up in stooks waiting to be carried. It is then ricked until it is carried to the de-seeding machine, which takes out the valuable linseed.

After "de-seeding," or "rippling," the flax is tied into bundles and immersed in water for from ten days to a fortnight. The water must be of quite exceptional purity and as a matter of fact it is the presence of pure water more than anything else which serves to localize the linen industry. The waters of the Lys in Belgium, and of parts of Ulster are supposed to be the best for this operation of rotting or "retting" the flax. The bundles are stood nearly upright in small pools or in the stream in such manner that, by means of fairly close packing, they do not touch the bottom. Fermentation sets in, attacking only the non-fibrous parts which tend to drop to the bottom.

In Russia and Canada much of the flax is retted by simply being spread out in fields, and even in other districts the flax is best dried out on the grass after the ordinary retting process (grass bleached linen).

Various artificial methods of retting flax have been described, but they do not appear to yield such good quality fibres as the processes given above.

After the retted flax is dry it can be rolled out by fluted rollers, which break up the non-fibrous part, and it is then ready for

scutching, which consists essentially in further rolling out the flax with fluted rollers and beating out the woody matter with revolving paddles, although some scutching is still done by hand. The scutched fibre is "heckled" by gripping the ends in between iron plates and lowering it between two revolving bands of interlocking teeth; these, of course, straighten out the fibres and at the same time tear away the tow (short or tangled fibres). The tow is carried down by the bands and removed by a brush at the bottom, after which it is separately treated similarly to jute. When the longer fibres are straightened as much as possible between the first bands, they move along to a second pair with closer set teeth, and so on until a fineness of up to sixty teeth to the inch is reached. The tow is, of course, removed each time.

The fibres are now made into slivers similarly to cotton, and drawn out with doubling in the same way until ultimately as many as 100,000 slivers may be represented in the final "roving" which has some twist on it. The spinning of the roving into thread is also similar to the same operation with cotton, with the important exception that fine flax thread can only be worked wet and warm, and this condition is secured by passing the fibre, before spinning, through a bath of water heated to about 50°C. This is not necessary for coarser work. The nomenclature indicating fineness or coarseness of flax yarn is fixed by law in Britain as the number of 300-yd. lengths (leas) which weigh a pound.

The weaving of flax is similar to the weaving of cotton. Individual flax fibres are smoother, more cylindrical, and stronger than those of cotton, and therefore linen is smoother and stronger than cotton cloth, but the uses of linen are in general similar to those of fine cotton, and this material is being substituted for linen in an increasing degree. The more important special uses are for table linen, bed linen, towels, fine shirts, lace and aeroplane wing fabric.

The presence of cotton in linen may be detected by treating for about a minute with a boiling solution of caustic potash, which turns linen a dark yellow colour but makes cotton a pale yellow only or leaves it white.

**JUTE.**—Jute is a fibre derived from Indian plants (*Corchorus capsularis* and *Corchorus olitorius*) and grown chiefly in Bengal, the

Sunderbunds, China, Formosa and Malaysia. The plants are annuals and either grow *in situ* from seed sown in spring, or else they are planted out from nursery beds. A high temperature and rainfall are necessary for the successful cultivation of jute, which, under the appropriate conditions, grows very fast and can be harvested in three months from seed-time. The stems are by that time from 5 to 10 ft. high and are cut by hand, or sometimes pulled by hand like flax. After cutting, the crop is stacked for a short time and then retted similarly to flax. The removal of the woody part is done by hand and completed by slashing the jute on the surface of the water. The fibre so prepared is then wrung and hung on lines in the sun, to dry, after which it is graded and compressed, like cotton, into bales for export.

Jute fibres are coarser and weaker than flax and, further, they deteriorate on keeping.

**Manufacture.**—Jute has only been manufactured in Europe within the last 100 years, but it is now worked on a vast scale in Dundee, London, and various continental centres as well as, though to a smaller extent, in America. Jute spinning and weaving is also an important industry in Calcutta. In manufacture the compressed jute is “opened” and then softened by passing it between many fluted rollers and at the same time treating it with oil and water. This operation is called “batching.” After the oil has become thoroughly incorporated the fibre is then carded (and flax tow is treated similarly) by combing between pins on rollers, and this operation may be repeated. The carded fibre is then made into slivers and drawn, spun, and woven similarly to cotton.

Jute is used particularly for gunny bags, wrappings (Hessians), carpets, rugs, sackings, etc., and rope. The young leaves of jute are edible.

**HEMPS.**—There are various cordage materials called hemp, but true hemp is derived from a plant (*Cannabis sativa*) which is grown in China, Japan, Malaysia, India, U.S.A., Russia, Turkey, Italy, etc. Apart from its fibre the plant is grown in the East for the drug “*bang*,” which can be prepared from it, and which has stimulating and even maddening effects.

Hemp is an annual plant growing up to 10 or more feet in height.

The seeds are sown in spring on well-manured ground, and can be sown on the same land several years in succession.

Hemp is dioecious, *i.e.* there are male plants and female plants, and the male plant produces the finer fibre. Since the male plant, of course, produces no seeds it can be harvested much earlier than the female, which has to wait until the seeds are ripe. The plants are cut down, and in the case of the female plant the seeds are removed. The stems are then "retted" like flax and afterwards dried either in the air or in ovens. The woody matter is removed by beating and the fibre then scutched, etc., similarly to flax.

Hemp is very similar to flax, although generally not so fine. Piedmont hemp, however, is almost equal to flax and is often woven with it. It can be used for all purposes for which flax yarn can be used, except the finest work, and for coarser work, including towelling, sheeting, tarpaulin, coal sacks, sail cloth, etc., and for ropes and cordage, rugs, carpets, etc.

The seeds of hemp are used for cage bird seed and as sources of oil and cattle cake. The oil is used in soft soap, in paint, and in varnish.

Bhang is the dried leaves and small twigs. Gauga or gauza, from which hashish is made, is the female flower heads, and Charas is the resin which exudes from the hemp plant. All three of these substances are eaten or smoked in various forms producing narcotic and intoxicating effects. It has been alleged, however, that these products come from another variety of the plant which produces a relatively worthless fibre.

**MANILA HEMP.**—Manila hemp is a product of the Philippine Islands and is obtained from the leaf-sheaths or stem (they are the same) of a tree (*Musa textilis*), which is really a banana tree with an inedible fruit. The plants are propagated from the offshoots or suckers which, when transplanted, become mature in about three years. The young tree is then cut down and the exterior of the trunk, consisting of scale-like leaf sheaths, is stripped off and cut into thin slices. These slices are forced under a dull-edged blade which separates the fibres from the remainder.

Manila hemp is the best of all rope materials for marine use but is too stiff for cordage. (A rope is above 1 in. in diameter, a cord is less than that.) It is sometimes spun on a "rope walk" in the



Philippines, by hand, but in general is machine spun in factories after scutching, heckling, etc., similar to flax.

**SISAL HEMP.**—Sisal hemp, or hennequin (*hennequen*), is a fibre obtained from the leaves of *Agave rigida*, grown in Central America and the West Indies, whilst it has been successfully introduced to India, East Africa and Queensland. The fibre takes its name from Sisal in Yucatan, one of the ports from which it is exported. The plant thrives on poor soil and is propagated from suckers like hemp or from "sets" like onions. The outer leaves are harvested annually until the plant flowers, after which it dies. This it may do when it is from ten to thirty years old. The leaves are passed through a combing machine to separate the fibres, which are washed during the operation. The fibres are then dried in the sun for export. Like Manila, it is best used for bigger ropes, and it is the next best material to that fibre for that purpose. It is too hard for cordage.

Other *agave* leaves also produce fibres, especially the well-known maguey (century flowering plant) which yields a fibre like jute, and the *agave heteracantha*, which gives Istle or Mexican fibre.

**NEW ZEALAND FLAX.**—New Zealand Flax, or Phormium (*Phormium tenax*), is a plant of the lily family growing in New Zealand and certain near-by islands. It has long spiky leaves which are crushed, combed, and washed to produce the fibre. This is then dried for export and is used for ropes, cordage, etc.

**RAMIE FIBRE.**—Ramie fibre, China grass, or Rhea, are the bast fibres of *Boehmeria nivea* and *Boehmeria utilis* or *Boehmeria tenacissima*. They are stingless nettles growing up to about 5 ft. in height in China, Sumatra, Malaysia, and India. They produce, normally speaking, three crops a year, which are treated by either hand or machinery. By hand treatment it may take a man as much as four days to produce a pound of fibre, although normally he would produce twice that amount. In spite of this very expensive labour cost, however, the hand made fibre can compete with the machine product because, amongst other things, the "grass" is best worked green, and also because, although it is possible to work the dried material, the plant is usually harvested during the wet monsoon and consequently must be artificially dried, for if stacked green it rots; and for this latter reason also it cannot be retted

like flax. The machines, generally speaking, roll and beat the "grass" at the same time as washing it. The difficulties do not end here, however, for ramie may contain up to 30 per cent of gum which is very difficult to remove, although this can be done by live steam, dilute soda, bleaching powder, and dilute acid successively applied.

Ramie is a long, lustrous, strong fibre, which is superior to cotton and can be used for lace, damask, plush, etc. It is also used very widely for incandescent mantle fabric. The only difficulty in the way of a very much wider use of China grass is the cost of production.

**PINE-APPLE FIBRE.**—The leaves of the pine-apple are worked in South-Eastern Asia and the Philippines, for their fibres, which are used locally for the manufacture of cloth.

**BRUSH MATERIAL.**—Artists' pencils are made by hand from sable ichneumon or camel hair made into bundles with the centre ones protruding to a point. These bundles are then mounted in hot, wet quills or into metal sockets.

Scouring brushes, tooth brushes, etc., are chiefly made from the bristles of the half-wild pigs of Eastern Europe. The bristles from domesticated pigs are not nearly so valuable, since breeding reduces their elasticity and strength. Badger hair is used for shaving brushes and gilding brushes because of its great elasticity.

Brushes are also made from the stems of the broom millet in Italy, and from the roots of the Mexican grass in France and Germany. Bass-brooms are made from the fibres of the leaves and leaf-sheaths of various pissaba palms growing in Brazil and Equatorial Africa.

Long-haired brooms are often made from oiled kitul fibre from the kitul palm of Ceylon and India.

Iron wire and spun glass are also made into brushes for special purposes.

**WOOL. Animal Fibres.**—The most important of all the animal fibres is sheep's wool. This material has been used from the very earliest times by men in very early stages of development.

For a long time England was one of the most important wool-producing countries in the world, and raw wool was England's most important export. English wool was long and of the Leicester type, whilst the best short wool came from the Spanish merino

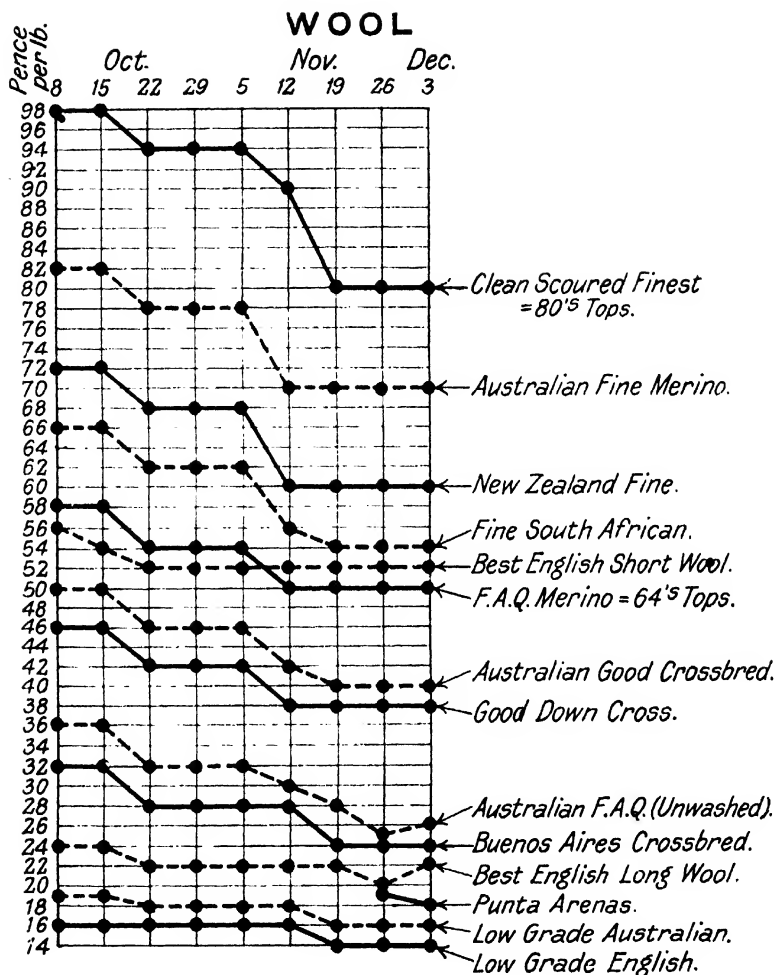
sheep. Nowadays, however, the centres of wool production have shifted to the southern hemisphere, for a variety of reasons, including of course, the cheapness of land there. But a very important cause is that when sheep are reared near populous areas it will probably pay better to breed for mutton than for wool and the increase in cold storage will help to extend the mutton-producing "field" all over the world. However, crosses between fine wool merinos and Leicesters produce a sheep giving plenty of mutton and plenty of wool, and cross-breeds of this type are very largely reared in Australia, New Zealand, Argentina, and South Africa.

Natural wool contains a large amount, up to 50 per cent, of grease, and this would be, of course, a great charge upon transport, so that in some cases the wool is scoured before being sent away. Scoured wool, however, does not travel so well as wool "in the grease," and does not fetch so high a price in London, therefore the bulk of exported wool is exported unscoured. In Australia the farmer is advanced a portion of the value of the wool which, however, remains his property (although sent away in bulk by the lender of the money) until it is sold (usually in London). The wool is usually sold and bought by brokers at sales held every two months in London.

The order of value of wool from different breeds of sheep can best be illustrated by the diagram on page 279, reproduced from the *Times Trade Supplement*, but it should be remembered that all the prices there shown are phenomenally high.

**PROPERTIES OF WOOL.**—Wool fibre is round sectioned, rough-edged, elastic, and as a rule wavy. In its natural state it is greasy and is thus prevented from "felting." It is for this reason that unscoured wool travels better than scoured wool. The wool of mountain sheep is much coarser and straighter than that from merino sheep.

Wool, unlike cotton, is very easily attacked and dissolved by hot solutions of alkalis, although it can be "mercerized" by cold alkaline solutions. For the above reasons it is evident that only cool to warm, dilute, solutions of washing soda can be used in scouring wool. Dilute acids do not have much effect on wool beyond causing it to dye more easily, though hot strong acids completely dissolve it.



By permission of the Times Trade Supplement.

VALUE OF WOOL FROM DIFFERENT BREEDS OF SHEEP

The detection of cotton admixed with wool is possible by—

(a) Treatment with hot strong alkali which dissolves the wool, leaving the cotton ; and

(b) Treatment with hot dilute sulphuric acid which dissolves the cotton, leaving the wool.

Wools are, for trade purposes, divided into three main classes—

(1) Long stapled from Leicester, Lincoln, etc., sheep.

(2) Intermediate from South Downs, Cheviots, and cross bred “ mutton ” sheep, e.g. New Zealand, Argentina, etc.

(3) Short stapled wool or merino wool, from pure bred sheep in Australia, Cape Province, and Argentina.

The properties may be expressed in a table form as follows—

	Long Wool	Intermediate	Short Staple.
Length of Fibre . . . . .	6" - 12"	3" - 8"	2" - 5"
Diameter . . . . .	·001"	·0008"	·0005"
Serrations per inch . . . . .	1,000	2,000	2,800
Chief use . . . . .	Worsted	Worsted, Tweeds, etc.	Fine Woollens, Broadcloth

Another important material is old cloth, which is used for the manufacture of shoddy and also is incorporated with new wool in the preparation of various cloths.

Rags and old clothes are prepared for spinning by being torn up by the large number of teeth set upon a rapidly revolving roller. If cotton be admixed with wool in the rags it can be removed by taking advantage of the previously-mentioned fact that whereas wool is not much affected by dilute sulphuric acid cotton is destroyed by it. The rags, therefore, are treated with dilute sulphuric acid, which destroys the cotton, leaving only the wool which can be washed and dried. Of course, cloth prepared from material so treated will be of inferior quality and, generally speaking, since the older wool is the less elastic and wavy, shoddy is much more likely to go shapeless and baggy than is cloth from raw wool.

**MANUFACTURE OF WOOL.**—Wool is generally gently torn open into a loose texture before washing by the toothed rollers of a machine, called a willey, after which it is scoured by passing through a succession of alkaline baths, being mechanically wrung out between each. It is finally washed in water and dried.

The scoured wool will still contain solid impurities, however,

such as dirt and "burrs," and all these must be got rid of. Burrs are small pea-sized closer-than-a-brother sticking objects which are often present in imported wool, and they are very difficult to remove. When they are present in poor wool they may be removed by acid, but they are usually knocked out by turning the wool upon a toothed roller against which revolving blades are made to strike.

**Carding.**—All wool, except long wool for worsted, is carded, although, if worsted yarns are to be made the process is carried out more gently than for woollens. Carding consists essentially in forcing the wool, which is oiled to keep it supple, between toothed rollers working at different rates so as to spread the wool into an even layer of very loose texture. All wool is treated several times with teeth increasingly finely set. When the wool gets to this stage the difference between worsted manufacture and woollen manufacture must be made, although it may be made before. For, if long wool is being used, it has been passed through flat, relatively wide-toothed falling combs instead of being carded. In any case all worsted yarn, whether carded or not, is passed through ~~two finer-toothed~~ "gill boxes," as they are called, and made into slivers before being submitted to the operation technically called "combing," and it is this process which makes worsted, as distinct from woollen yarn. Combing secures that the fibres are all parallel, but it also selects only the long fibres and rejects the short ones, for worsteds are spun only from long fibres. This is done in various ways, but in all cases the teeth which do the combing are kept warm. One of the most frequently used combing machines, the Noble machine, consists essentially of a revolving circle which carries the slivers round with it and pays them out automatically on to the surface of the circle which is toothed. Inside the large circle are two lesser toothed circles, which are independent of each other, and which also revolve. These are internally tangential to the large circle, and at the momentary points of contact brushes force the slivers on to the teeth of the inner and outer circles simultaneously. As the circles travel on the former points of contact become increasingly distant and the long fibres naturally get pulled straight between the two wheels. With increased distance, however, the fibres are pulled away at one end or the other and travel

on one wheel only with one end projecting. These ends are gripped by a band and rollers and pass on to form the " tops " of commerce. Meanwhile the shorter fibres have been left between the teeth, and these " noils " are removed by intruding blades and sent away to be used in the manufacture of woollens, for they are too short for worsted, or they may be made into blankets or felts. The combed wool is then, in the same machine, condensed into one sliver. The slivers from different machines are condensed into one in " gill boxes " to secure evenness and uniformity and further drawn somewhat like cotton until, at length, a twist is just put on the roving which is then ready for spinning.

If, instead of worsted, woollens are to be made, the operations have been very much simpler, for the layer of loose wool from the carding machine will have been rolled into slivers between rollers on which the teeth of one are opposed to a smooth surface on the other alternately. Therefore the sheet will be torn into strips every other one of which will go upwards on the teeth of the top roller and the remainder towards the teeth of the bottom roller. These slivers are then condensed ready to be spun.

The spinning of wool is not markedly different in principle from the spinning of most other textile fabrics and need hardly be described.

After the yarn has been woven into cloth there is, in the case of worsteds, little more to do, but woollens are " fulled " by shrinking them in soap solution and at the same time rolling them so as to secure evenness of texture. Then if a nap is required the surface is picked up by teazles and the loops shaved down into projecting individual hairs.

Woollens may be dyed as yarn or in the piece, according to the character of the cloth made or to be made.

The wools of the vicugna and the llama are used as sheep's wool in the preparation of best quality yarns.

**MOHAIR.**—Mohair is the hair of a special breed of goat reared originally in the province of Angora, in Asiatic Turkey. It is still bred there but crosses of it have also been introduced into South Africa and Australia. The fibres are long and silky but not nearly so serrated as in wool, and therefore mohair is more difficult to spin than wool. Mohair yarn is largely used in the woollen industry

admixed with wool and for special cloths, alpacas, which are made more or less exclusively from it, but in this direction mohair has suffered from the competition of mercerized cotton. Mohair is also extensively employed for braided work, bootlaces, and for carpets and rugs.

Camel hair is used in the manufacture of cloths, carpets, and artists' brushes of inferior quality.

**SILK.**—The caterpillars of many moths make cocoons of a silky material, but the silk worm (*Bombyx mori*) and a few others are the only ones of commercial importance.

The chief food of the ordinary silk-worm is mulberry leaves, and so the region in which they can be competitively reared is necessarily confined to that in which the mulberry grows freely. There is, however, a further limitation in that the rearing of silk-worms requires much hand labour, and so in practice raw silk is only produced in bulk in sub-tropical countries in which labour is cheap, e.g. China, Japan, Italy, Syria, a portion of France and Spain.

The moths are often interned in little bags to lay their eggs which, as they hatch out into caterpillars, are transferred to trays where they are regularly fed with mulberry leaves. For about a month the caterpillars grow very rapidly, and in the course of that time slough their skins four times and then are ready to spin their cocoons. If, however, when they are at this stage they are steeped in acetic acid and the glands containing the silk removed, these latter can be drawn out into the transparent and immensely strong gut used for fishing casts, etc., and this branch of the industry is carried out in Spain, Italy, and China. Normally, however, they project, from a tiny orifice in the head, a very thin thread which they wind round themselves by gently undulating the body. The thread so emitted is simultaneously "gummed" from other glands. The cocoons are hand-stripped from the mulberry twigs to which they are attached and, if they are required for breeding purposes, are separately stored in partitioned boxes. If, however, as is usual, they are for silk only, the chrysalis is killed by hot water or hot air, or by freezing, since otherwise on its emergence the moth would cut the silk.

Each cocoon consists of about 1,000 yds. of silk of which, as a rule,



about 500 yds. can be unwound and reeled whilst the remainder is treated, along with the broken cocoons which have furnished the breeding moths, somewhat similarly to cotton, and yields the relatively inferior spun silk. The strand, or "bave," has a diameter of about .0005 in., is smooth, like a glass rod, and consists of inner rods of silk with an outer layer of gum.

**Manufacture.**—The cocoons are immersed in a bath of nearly boiling, very dilute, alkali solution for a few minutes, which has the effect of softening the "gum" which, as previously mentioned, surrounds the silk fibres and causes them to stick together. The bath is then stirred with a brush of twigs to which the loosened outer fibres adhere so that the ends of the threads can be found. As soon as this is done the cocoons are placed in water at a temperature of about 65° C. and the ends of five or more threads passed together through a small orifice and on to a winder, but in order to secure the thorough incorporation of these five or more separate threads into one, they are wound, about twice, round another similar set of five or more strands which are conducted to another reel and separately wound. By being pulled round one another each set becomes amalgamated by its own gum into one thread. The threads are then rewound and somewhat twisted before spinning so that they shall the more readily amalgamate with other threads, for silk fibres do not have the serrations which cause cotton and wool so easily to unite into yarn. The twist also secures that when degummed the fibres cemented by the previous process shall not separate again. For light wefts, as a matter of fact, the twisted strands can be used without doubling, but for warps and stronger threads two or more of the twisted (thrown) threads are spun together in the reverse direction from the first twist. Silk is sold in skeins of 450 metres, and the number of half decigrams which this length weighs is the count of the silk.

Since silk is very hygroscopic, and is often sold by weight at this stage of manufacture, it is necessary to define the amount of water which it should contain, and this is done by heating it for a few hours to about 120° C., weighing it immediately it cools and adding 11 per cent to that weight as the probable amount of water which will be absorbed.

**Scouring.**—Silk required for all materials but those which are stiff, like gauze and crepe, must now be “degummed” or scoured in order to remove the harsh gum and leave only the “silky” fibre. This is done by heating, not boiling, in, first a strong and then a weaker, soap solution, washing in water and “hydro”-ing. Silk for white goods is then bleached from its natural yellow by sulphur dioxide and again washed.

**Spun Silk.**—Waste silks from the various processes, cocoons from the breeding moths, and all the non-reelable fibre and floss on the other cocoons are spun into yarn by special processes consisting essentially in (1) degumming by natural fermentation (shappe), or (1A) degumming by soap solution similar to the method with finished yarn (discharging). Then (2) passing the fibres between pinned rollers which straighten them into a lap, and (3) combing them nearly parallel, and selecting the long and rejecting the short, fibres. Subsequently to these processes slivers are made, doubled and drawn and spun like other textiles.

Silks from other larvae are used in commerce especially from *Antheraea pernyi* of China which feeds on oak leaves, and the *Antheraea mylitta* of India, which feeds on the leaves of *Zizyphus jujuba*. The larvae from each of these species yields a silk known in trade as Tussah or Tussore.

**Silk Dyeing.**—Silk dyeing has one feature which characterizes it as against all other textiles, and that is the great gain in weight which the fibre can be made to receive. Appropriate dyes, *e.g.* those containing stannic chloride, can add 400–800 per cent to the weight of the silk. Since this is always accompanied by a weakening of the fibre it is obviously a bad practice and much to be deprecated. Generally speaking, parti-coloured silks are not so durable as other textiles.

**CARPETS.**—Carpet-making may, or may not be, a separate branch of the textile industry. For instance, Scottish or reversible carpets are woven in precisely the same way as woollen cloth but with coarser material, but most other carpets have special features in their manufacture which constitute carpet-making as a separate industry.

The best carpets are hand-made and usually consist of a strong close warp of cotton, hemp, wool, or even silk upon

which short pieces of wool, mohair, camel hair, etc., are tied with both loose ends pointing one way. Weft threads are then taken across.

Machine made carpets, other than reversible carpets, usually have a jute or linen background. Over this straight iron wires are laid and then worsted or other yarn is carried over the wires and into the background forming, when the wires are removed, a series of loops. This is a Brussels carpet. Sometimes, however, the loops are all cut at their summits and then a Wilton carpet is produced. If a Brussels carpet be made in which the pattern is made, not by weaving but by printing on the threads before making the loops (it is then, of course, much longer than its finished size), the result is a tapestry carpet.

In an Axminster carpet the pattern is first woven on to a fine background and this is then incorporated in the carpet proper.

**ASBESTOS.**—Asbestos is a name somewhat loosely applied to a number of minerals which can be obtained in a fibrous condition. The word itself means “unquenchable” or “inextinguishable,” and is an allusion to the fact that it was used for cremation windings and temple “linen” by the ancients. In commerce the name is chiefly given to “tremolite” asbestos or Italian asbestos from the Piedmont Alps and to “serpentine” asbestos from the province of Quebec.

Asbestos owes its fibrous character to the enormous length of its crystals which are readily separable, and these in Italian asbestos may be some feet long, whilst in Canadian asbestos they are only an inch or so long.

Asbestos of both kinds is not affected by ordinary heat, but serpentine asbestos can be fused at red heat, whilst tremolite asbestos remains unaffected at very much higher temperatures. Tremolite, moreover, is unattacked by all ordinary acids.

Tremolite is therefore used for a filtering medium in chemical practice and for paper, cardboard, etc., for laboratory use.

Serpentine asbestos, although shorter fibred, is better suited than tremolite for spinning and weaving, but tremolite can be used for this purpose. Asbestos fabric is made into fire-proof clothing, theatre curtains, etc., and asbestos cord is wrapped in steam joints to make them tight. Large quantities of asbestos are put into

packings, because of its very poor heat conduction properties, for boilers, ovens, refrigeration apparatus, etc., and it is also put up, mixed with cement, etc., in the form of sheets and boards for fire-proof construction.

Asbestos waste and low grade asbestos is used in the building trade under the name of "asbestic."

## CHAPTER XXVII

### DYES

A **DYE** is essentially a coloured solution which can be absorbed by, and give a colour to, certain other substances. It differs from a paint chiefly in the fact that the latter is usually a finely divided solid which is stuck on to the surface of the article painted.

Dyes have been used from time immemorial, and Egyptian mummy cloths, for example, show that a very long time ago the technology of dyeing was far advanced.

Some of the more important natural dyes will first be given below, followed by a short general account of synthetic dyes, but it should be remembered that there is at the present time practically no natural dye that could not be done without, unless an exception be made in the case of certain substances like sumach, which dye and tan at the same time.

**INDIGO.**—Indigo and logwood are almost the only dyes used on a large scale in which the natural product can compete at all with the synthetic article and even in this case the use of natural indigo has been enormously reduced. Indigo has been used as a dye for a very long time and is one of the substances, already alluded to, with which Egyptian mummy cloths were coloured, and is related chemically to woad.

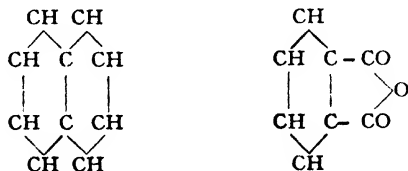
Indigo was obtained from the indigo plant (*Indigofera tinctoria*) which is cultivated in India (chiefly), Java, Natal, China, and other tropical areas. The plant is grown from seed sown in drills in February on well ploughed and manured ground, and by about the middle of June the plants, which are by then 3–5 ft. high, are fit for cutting, but a second and a third crop are subsequently obtained. The plants are usually cut before daybreak, well bruised with sticks, and packed at once, nearly upright, in steeping tanks about 4 ft. deep and of about 6,000 gallons capacity. The plants are battened down and the vat filled up with water. In eleven or twelve hours the steeping is complete and the soluble colouring matter, which is at this stage yellow in colour, is extracted. The liquid is then run off into “beating” vats whence the pale-coloured solution is oxidized to indigo blue either by agitation with a blast of air or by beating with paddles. When the oxidation is judged

to be complete, the contents of the vat are allowed to settle, and a bottom layer of semi-solid indigo-blue obtained, which is pressed into cubes for the market.

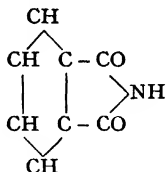
**SYNTHETIC INDIGO.**—There is scarcely a chemically-produced substance the preparation of which has involved more labour and expense than indigo, and it is estimated that before the present method of preparing indigo from naphthalene was made a commercial success one firm alone, the Badische Anilin-und Soda Fabrik, had spent £1,000,000 on research, experiment, and plant in connection with the problem. After the problem of the constitution of indigo had been determined syntheses were effected, but in all cases but one the cost of material or fuel on the manufacturing scale did not give the process great success in competition with the natural product where, normally speaking, no fuel is necessary in the tropical climates where the dye is extracted. Some of these syntheses, too, paid when conducted on a limited scale but not on a large scale, since they were based upon the use of by-products which are available in restricted quantity only. Using these, indigo could be made at reasonable cost, but as soon as these substances had to be produced especially for indigo, then their cost was much increased, and indigo from such sources would be too dear, and it may be mentioned that this is one of the problems which arises most frequently in chemical manufacture.

The task which the Badische company set themselves then was to prepare indigo by a cheap process from a cheap source which existed in sufficient quantity to produce all the indigo required (about 5,000 tons a year) without making the starting product too dear to use. Eventually naphthalene was decided on since it was a waste product, much of which was burnt for lamp black or was left in solution in the heavy oils from coal tar.

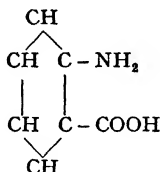
Briefly, naphthalene is treated with fuming sulphuric acid and mercury and so oxidized to phthalic anhydride—



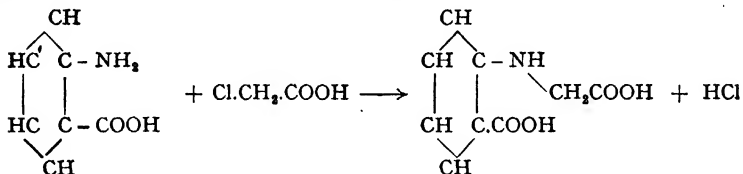
and the phthalic anhydride treated with ammonia under pressure whereby it becomes converted into phthalimide—



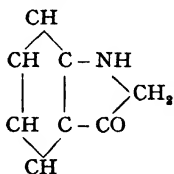
and phthalimide, when treated with sodium hypochlorite (NaO Cl), gives anthranilic acid—



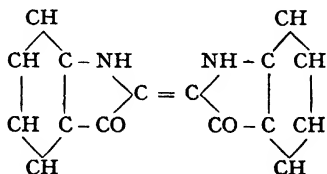
The anthranilic acid, on treating with monochlor acetic acid, gives phenyl glycoll ortho-carboxylic acid—



and this latter substance, after fusion with soda, yields indoxyl—



The indoxyl is then dissolved in water and air blown through to produce indigo—



Indigo is also produced on a large scale by the Hoechst Farbwerke.

It is interesting to notice that the manufacture of indigo has called into being other large industries, *e.g.* the contact process for the preparation of sulphuric acid, and the electrolytic preparation of chlorine, whilst a very large quantity (3,000 tons, representing over 4,000,000 cubic ft. of timber, per annum) of the acetic acid produced by the distillation of wood is utilized in the preparation of indigo.

Indigo itself is insoluble in water, and before using it for dyeing it is reduced to "indigo white," the "leuco" compound, as it is called, which is soluble in soda. The fabric or yarn to be dyed is placed in a bath of a solution of indigo white in soda and is then hung in the air, when the oxygen gradually changes the indigo white to indigo. An operation such as this is called vat dyeing.

Various bromine and sulphur derivatives of indigo are made and used as dyes on a commercial scale.

**Logwood** is obtained from the heart of *Haematoxylon campechianum*, which grows throughout Central America and the West Indies. The wood is made into chips or dust, which are built into heaps with a little water and left to ferment, though each heap must be repeatedly turned over to prevent over-heating. The fermented wood is then extracted with boiling water either under increased pressure or at the pressure of the atmosphere, or it may be extracted by diffusion (like sugar beet). The extract so made can then be evaporated to a paste or solid. Although logwood extract is itself red, yet logwood is chiefly used as a black dye and especially for silks. In fact, silk is dyed black almost exclusively with logwood. A typical black dye bath is made by ferric sulphate, sodium ferrocyanide, logwood extract, and subsequent treatment with chestnut extract.

**Brazil Wood** (*Caesalpinia brasiliensis*), from South America, **Peach Wood** (*Caesalpinia echinata*) from Mexico, and **Sapan Wood** (*Caesalpinia sappan*) from the East Indies and Japan all contain the same dye which has been called brasilein. They are used, though to only a slight extent, in the form of chips and raspings, to produce pinks and purples and to compound with other colours. They are not very fast dyes.



**Alkanet**, from the root of *Alcanna tinctoria*, is used chiefly for dyeing druggist's preparations, cosmetics, etc.

**Sandal Wood** (Saunders wood, red sanders, etc.) (*Pterocarpus santalinus*) from India and Monsoon Asia generally and from Madagascar, and Barwood (*Baphia nitida*) from Sierra Leone, yield reddish and claret dyes for woollens which must be mordanted. The colouring matter is practically insoluble in water, so the wool to be dyed is actually boiled up with the wood raspings themselves, and then dipped in the mordanting solution. These dyes are very fast to washing, etc., but are somewhat affected by light.

**Fustic** (Old Fustic, Cuba wood, yellow wood) (*Morus tinctoria*) grows in Northern South America, Central America and the West Indies. Boiling water extracts a colouring matter or the rasped wood can be used. It is used principally for wool and usually in connection with other dyes, requires a mordant, and produces shades of brown.

Young Fustic from *Rhus cotinus*, of the West Indies, is not to be confounded with Old Fustic, and is not now used in the dyeing industry.

**Annatto**, which is a yellow dye much used for colouring milk, butter and margarine, is obtained from the fermented seeds of *Bixa orellana* of Central America.

**Quercetrian Bark** is obtained from the *Quercus nigra*, an oak which is a native of Eastern and South-Eastern U.S.A. The inner part of the bark only is used, and this is often extracted with very dilute boiling sulphuric acid to produce the colouring principle which is known as "flavin." Flavin is used to dye wool, yellow, orange, or red, often in conjunction with other dyes. The dye must be mordanted in.

**Turmeric** is the ground dry rhizome of *Curcuma tinctoria*, which grows in Monsoon Asia. Extracts can be made by treating the de-resinified rhizomes with soda.

Turmeric is a substantive dye like indigo, *i.e.* it requires no mordant in order to make it adhere to the fabric although metallic salts are sometimes used to vary its colour. It dyes yellow, brown, and orange. Turmeric is used to colour curry powder, and is also employed as an indicator in laboratory practice.

**Persian Berries** are the fruit of *Rhamnus amygdalinus* and other similar plants grown in the Near East and the Mediterranean countries. Aqueous, or alcoholic extracts, are used in dyeing to give yellows, oranges, and greens.

**Orchil** is a red to yellow dye formed by fermenting certain "lichens" (*Roccella*, *Varcolaria*, etc.), and **Cudbear** is similarly made.

**Litmus**, which is much used as an indicator for detecting acidity and alkalinity in chemical practice, is prepared by drying and grinding up certain "lichens" (*Roccella*, *Lecanora*) from tropical and sub-tropical countries and standing with a mixture of alkalis. The whole is left to ferment with the production of a blue colour. Ammonium carbonate and chalk are then added and the blue mass pressed solid.

**ANIMAL DYES.**—**Cochineal** or Carmine is a female insect (*Coccus casti*) which is parasitic upon the *Cactus opuntia*, grown in Guatemala and the Canary Islands. After the males have flown away the female insects are brushed off into baskets and either baked or boiled, and an acre of cactus yields about  $2\frac{1}{2}$  cwt. of dye. Cochineal is used to a certain extent in dyeing wool red or carmine, according to the mordant, and also for colouring foods.

**SYNTHETIC DYES.**—The great majority of dye-stuffs used in industrial areas at the present time are synthetic preparations, and the importance of artificial dye production may be gauged to some extent from the fact that Germany alone produced in one year £10,600,000 worth of dyes.

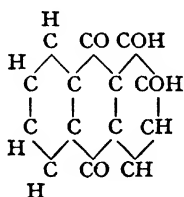
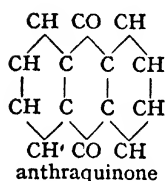
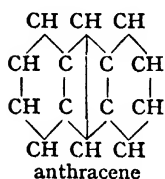
**Indigo**, the most important of all dyes, has already been discussed, and the next most important group of dye-stuffs are the Alizarin dyes which have been made since before history from the Madder plant, but which are now made exclusively, so far as organized industry is concerned, from a coal tar product.

**Alizarin** dyes can, very fortunately, be made from that highest boiling product of coal tar distillation which previously had no specific use. The starting product is anthracene, a white, usually yellow, crystalline solid melting at  $216^{\circ}\text{C}$ . and boiling at  $382^{\circ}\text{C}$ . The crude product from tar distillation must be very carefully purified and is first filter-pressed free of liquid oils and the solid anthracene thoroughly ground up. This is boiled up with a

limited quantity of light petroleum, which dissolves many impurities, and the cooled mixture filter-pressed. The anthracene left in the filter is then sublimed in steam and condensed by a fine spray of water into an almost impalpable powder.

The purified anthracene is then oxidized to anthraquinone by boiling up with a very dilute sulphuric acid solution of sodium dichromate in leaden tanks. The anthraquinone produced is then filter-pressed and, in England, heated for about twenty-four hours with about 300 per cent of concentrated (not fuming) sulphuric acid. This dissolves the anthraquinone without changing it, but most of the impurities are converted into sulphonic acids which, when the bath has cooled, and been diluted and the anthraquinone crystallized out, remain dissolved in the water. The anthraquinone is then heated with two successive quantities of fuming (Nordhausen) sulphuric acid and so converted into anthraquinone disulphonic acid, and the disulphonic acid fused with caustic soda, potassium chlorate, and water for a long time. By this means the purple sodium

salt of alizarin is produced and is freed from other reaction products and converted into alizarin itself by boiling with sulphuric acid.



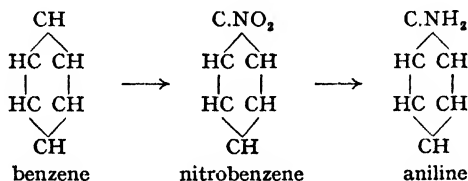
Alizarin, which is a yellow solid, is put on to the market as a yellow paste (with water).

Alizarin requires a mordant when it is used as a dye, and the particular mordant selected greatly modifies the colour produced. Turkey red oil, or aluminium salts, give the well-known Turkey red (a remarkably fast dye) with alizarin.

There are many derivatives of alizarin on the market and these have largely superseded the flavone dyes mentioned previously (*Quercitrin*, etc.), whilst more recently alizarin vat dyes have been prepared.

**ANILINE DYES.**—Aniline dyes, although they are not the most important dyes at the present time, are interesting historically as being the first organic dyestuffs to be synthetically produced, and of course they are still used commercially on a large scale. Aniline itself was first produced by the distillation of indigo with alkali, and since the indigo was obtained from *indigofera anil*, aniline was named from the second word of the name of the plant source.

Aniline, although it occurs in coal tar, is obtained commercially from the benzene which is distilled from that body. Benzene is treated with sulphuric and nitric acids under appropriate temperature conditions and is converted into the mono-nitro benzene (oil of mirbane), which is used as a cheap almond flavouring. Nitro benzene, when heated with scrap iron and hydrochloric acid, or scrap iron and steam (with ferrous chloride) is reduced to aniline.



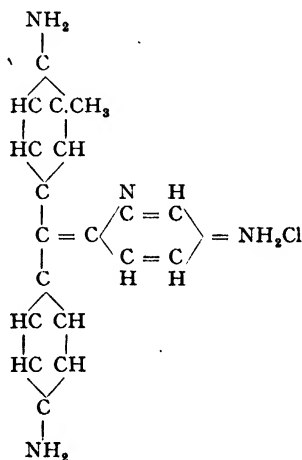
**Aniline Black** is one of the fastest of black dyes for cotton goods, although unless care be exercised in dyeing, the black, though fast to light and washing, may rub off. The dye is usually made in the fabric (vat dyeing) by dipping in a solution of aniline hydrochloride and some oxidizing agent, *e.g.* chromic acid, sodium chlorate, etc., and then passing the wet, but wrung, cloth through a chest containing steam and ammonia. (The latter is merely to prevent weakening of the fibres by the possible production of acids.) In the course of this operation the cloth blackens and oxidation is then completed by hot sodium dichromate.

**Rosaniline, Fuchsin or Magenta.**—Fuchsin, or magenta, is the hydrochloride of rosaniline, but these three names and others are given somewhat indiscriminately to base and salt. They are as much derivatives of toluidine as of aniline and were amongst the first artificial dyes to be produced. The requisite mixture of aniline and toluidine is prepared by manufacturers under the name of "aniline oil for red." It contains about one-third aniline, two-thirds of the remainder is ortho-toluidine and the rest of para toluidine ("Aniline oil for blue" is, approximately, aniline).

In the preparation of fuchsin some "aniline oil for red" is converted into its dry crystalline chloride, and this is dissolved up in the rest of the aniline oil. A weight of nitrobenzene equal to about 45 per cent of the weight of "aniline oil for red" used is added, and some iron borings or filings. The mixture is heated with stirring at about  $160^{\circ}$  with very careful regulation of the temperature. Unchanged aniline is dissolved out of the melt with hydrochloric acid and the dye itself extracted with water and crystallized.

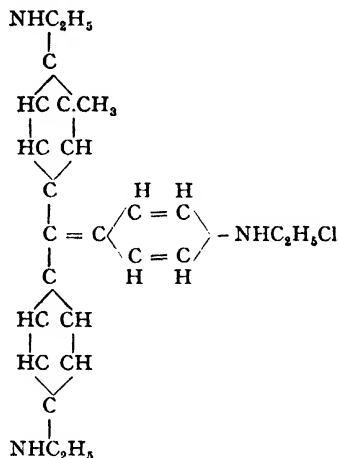
Rosaniline is—

"



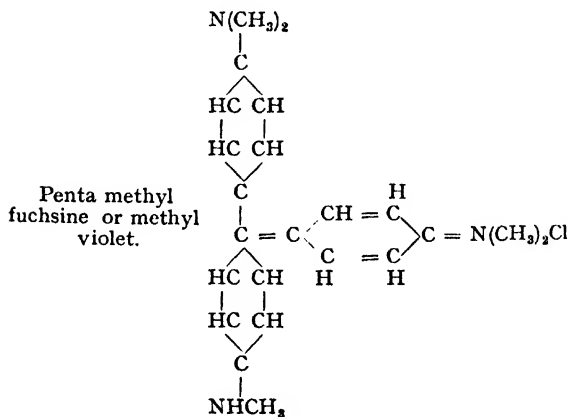
and the substitution of methyl groups for hydrogen in the  $\text{NH}_2$  radicles produces other dyes of deeper tint, thus, if rosaniline chloride be treated with alkali so as to release the base, and then

heated with an alcoholic caustic soda solution of ethyl iodide, a violet dye (Hoffmann's violet) is formed which has the structure—

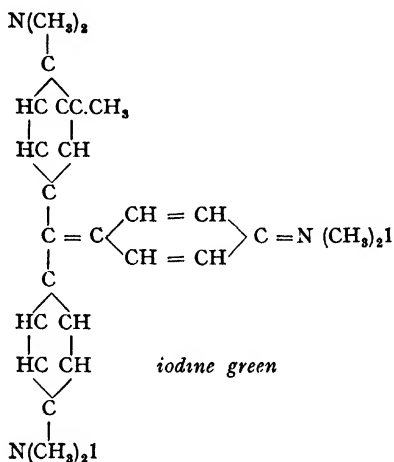


**Methyl Violet**, which is a dye closely allied to rosaniline, is manufactured from dimethyl aniline. It is the colouring matter in indelible pencils, and in hectograph ink.

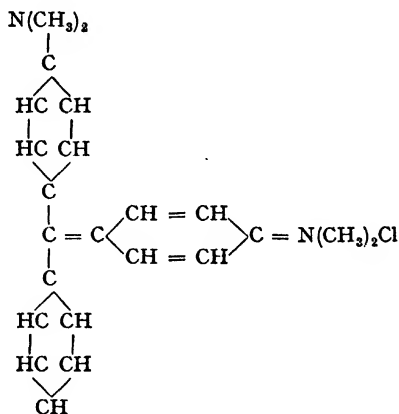
Dimethylaniline is itself a very important aniline derivative prepared by heating aniline and aniline hydrochloride under pressure with methyl alcohol. For methyl violet, dimethyl aniline, copper nitrate, salt, and dilute acetic acid are mixed with a large quantity of sand and heated. The melt is extracted with sulphuric acid—



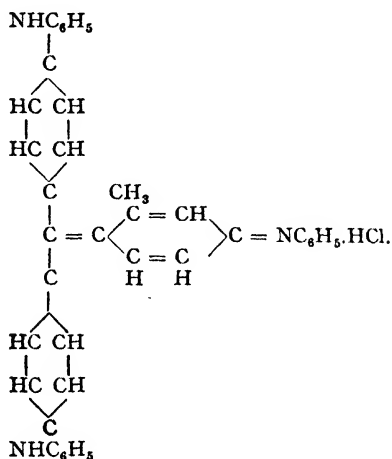
Methyl violet, on further methylation by heating with methyl iodide and methyl alcohol under pressure, gives *iodine green*—



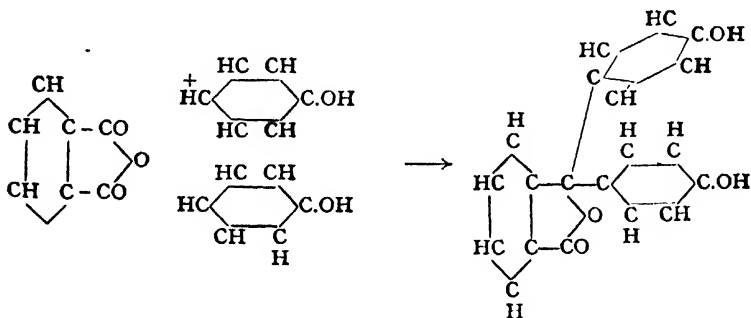
**Malachite Green** is prepared by heating dimethylaniline with benzaldehyde and water-free zinc chloride, subsequently oxidizing with lead dioxide and then the dye precipitated as a double salt with zinc chloride in which form it is usually marketed. Malachite green is a derivative of diphenyl methane—



**Aniline Blue** is prepared by boiling the acetate of rosaniline with aniline. It is a fine pure blue for animal fibres.



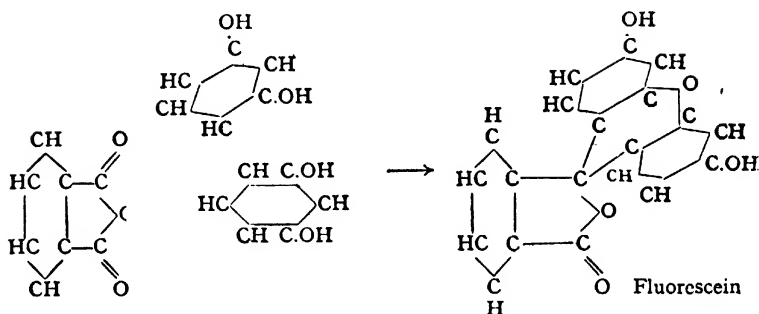
**PHTHALEINS.**—The simplest member of this group, phenol phthalein, is of no use as a dye, but it is used as an indicator in chemical practice and in medicine. It is made by boiling up phenol with phthalic anhydride and strong sulphuric acid—



If resorcinol (meta oxy phenol or meta dihydroxy benzene) be used instead of phenol a similar reaction takes place, but water



is also removed between two resorcinol nuclei so that a pyrone derivative is formed called fluorescein.



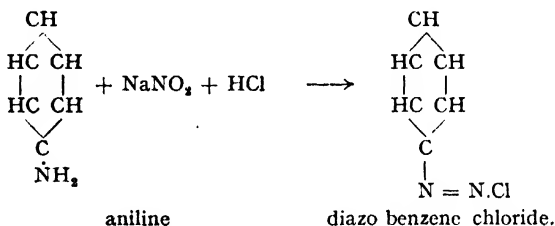
**Fluorescein** is red in acid and yellow in alkaline solution and very weak solutions which are alkaline show very marked and beautiful green fluorescence. Fluorescein is used to dye silk yellow. If a solution of fluorescein in caustic soda be mixed with a mixture of bromine and caustic soda, tetra brom fluorescein or *eosine* is obtained, which is a red dye soluble in water and fluorescent. About a  $1\frac{1}{4}$  per cent solution in water is ordinary red ink, and it dyes alum, mordanted cotton, and wool and silk a pink colour. If fluorescein be iodized instead of brominated, tetra-iodo-fluorescein is obtained. This is sold under the name of *Erythrosin*. It is sometimes used to dye silks a bluish tint, but it is chiefly and largely used in the photographic plate industry. It is well known that ordinary photographic plates are sensitive to blue but hardly affected by yellow, orange or red, and consequently, a blue or violet dress or flower photographs nearly white whilst a yellow or red one comes out practically black, and a red light, or even an orange one, can safely be used in development. This production of photographs of false light value, from the point of view of the human eye, is of course undesirable, and it has been found that erythrosin very greatly increases the sensitivity of silver bromide to yellow and orange light, so that plates which have been treated with it yield much improved photographs of yellow or orange objects. They are called orthochromatic plates.

Mention may here be made of Ethyl red (quinaldin-quinolin-ethyl-cyanin-iodide) and similar bodies which make silver bromide

almost equally sensitive to all the colours of the visible spectrum. Plates so treated are least sensitive to the green and are therefore developed and worked in a faint green light. They are called pan-chromatic plates.

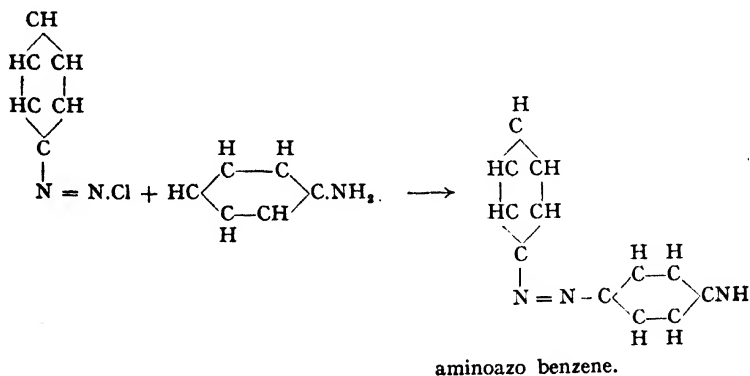
**AZO DYES.**—If an aromatic amine, *i.e.* the ammonia derivative of benzene or a benzene derivative be treated, in the cold, with nitrous acid or better, sodium nitrite and hydrochloric acid, a diazo compound results.

Thus—



Now these diazo benzene derivatives will usually unite at once with phenols, naphthols, amines, etc., with the production of dyes.

For instance, if aniline be added to diazo benzene chloride aminoazo benzene is produced—



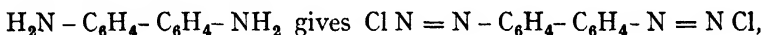
Aminoazo benzene is a yellow body, and its oxalate is used under the name of aniline yellow as a yellow dye for animal fibres and for tin-tannin mordanted cotton, but it is not a fast dye.

In this case, however, as in many others, sulphonation makes for permanence, and after aminoazo benzene has been appropriately treated with fuming sulphuric acid, *acid yellow*, which is more permanent than aniline yellow, is obtained.

There are, of course, a very large number of dyes of this class.

**DISAZO DYES.**—The remaining amino group in aminoazo benzene can also be diazotised and coupled with the production of another dye. Thus, if acid yellow be treated with sodium nitrite and hydrochloric acid, and then with a solution of sodium  $\beta$  naphtholate, the important red dye, Biebrich Scarlet, is prepared.

**DISAZO DYES FROM DIAMINES.**—Dyes containing two diazo groups can also be produced from the preliminary diazotization of diamines. Thus benzidine —

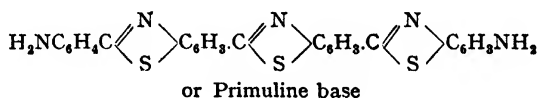


with sodium nitrite and hydrochloric acid, and this disazo compound will combine with all the ordinary coupling agents. In particular when coupled with the sulphonic acid of naphthylamine (naphthionic acid) it yields the very important Congo red.

$\text{H.O}_3\text{S NH}_2 - \text{C}_{10}\text{H}_5 - \text{N} = \text{N} - \text{C}_6\text{H}_4 - \text{C}_6\text{H}_4 - \text{N} = \text{N} - \text{C}_{10}\text{H}_5\text{NH}_2. \text{SO}_3\text{H}$  and this substance (a substantive dye) will dye cotton without a mordant.

**Bismarck Brown** and **Hessian Yellow** are other well-known dyes in this series.

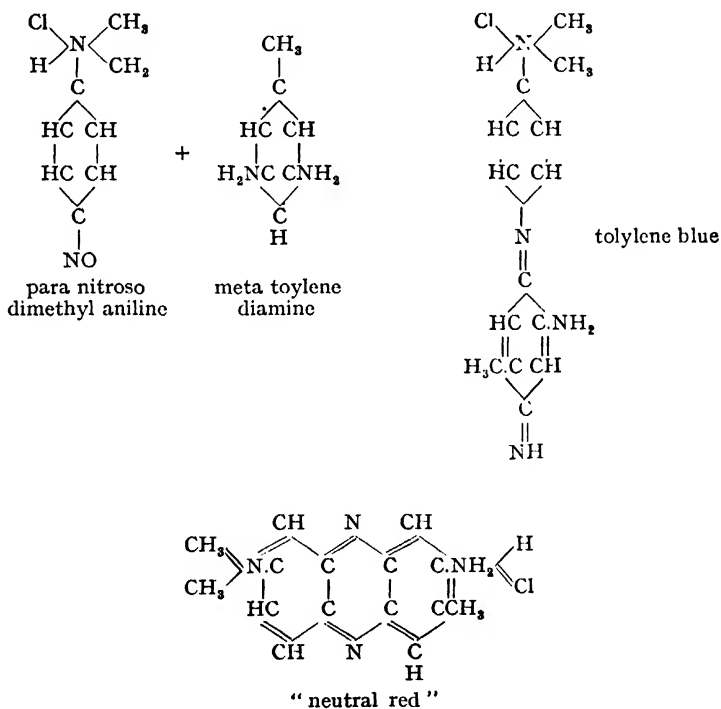
**PRIMULINE DYES.**—Primuline is obtained by the “thionation” of paratoluidine by simply heating paratoluidine with sulphur (with, of course, a condensation arrangement for distilled paratoluidine). The dehydro thio paratoluidine which results is then treated in the cold with fuming sulphuric acid. The commercial product primuline is the sulphonic acid of—



Primuline, when diazotized and coupled with salicylic acid, gives Oriol yellow, a substantive cotton dye.

Primuline, meta nitraniline, and other bases of substantive dyes are often used something like vat dyes. For instance, the fabric to be dyed may first of all be immersed in a solution of sodium salicylate and then placed in the bath of diazotized primuline, so that the dye is actually produced in the fibre itself.

**EURHODINE DYES.**—When para nitroso dimethyl aniline acts upon meta tolylenediamine, tolylene blue, which is of no commercial use as a dye, is formed, and when tolylene blue is boiled in solution it is converted into a very fast dye for cotton called neutral red—



"Neutral violet" can be formed similarly to neutral red from meta phenylene diamine and para amino dimethylaniline. It is used similarly to neutral red.



or cresol to prevent the growth of moulds, and some blue colouring matter, *e.g.* indigo sulphonie acid or aniline blue.

Such an ink is first blue, due to the blue dye it contains, and, as a blue ink, is absorbed by the paper. But in the course of a few days the ferrous gallate is oxidized to black insoluble ferric gallate, which is thus formed right in the fibres of the paper and is therefore indelible.

Copying inks are aqueous solutions of aniline dyes with a little glycerine added.

Marking ink is chiefly an ammoniacal solution of silver nitrate containing some gum. After this has been used to write on the material it is heated (usually by a hot "iron") and black metallic silver is precipitated in the fibre.

The "marking nut" is the fruit of *Anarcadium orientale* (India), and when extracted with water and made alkaline forms a permanent marking ink. Cashew nut (India and Tropical America) can be used similarly.

**DYEING.**—Although dyeing is a process and not a commodity, and therefore falls outside the scope of this book, it may, nevertheless, be as well to state baldly the principles upon which dyeing depends.

Wool, silk, and other animal fibres contain certain amino acids, *i.e.* acids containing the  $\text{NH}_2$  group, and as has been shown, bodies containing this group are very reactive coupling with diazo compounds, etc. Therefore in many cases these components of the animal fibre actually combine with the dye so that the dye is as much a part of the fibre as any other constituent.

Cotton, on the other hand, is practically pure cellulose and will not combine chemically with most dyes, and, except for the recently introduced substantive cotton dyes and indigo, some third body, which will combine at once with the dye and the cotton, may be introduced, and this is called the mordant. Such bodies are the tannins and lead salts. Other cotton mordants, *e.g.* aluminium acetate, work in a different manner. In this case, and in basic salts generally, the cellulose appears to precipitate, uncombined, in the fibre, aluminium and other metallic hydroxides, and these combine with the dye. Linen is more difficult to dye than cotton.

Printing is carried out by machines which have etched copper rollers, as many in number as there are colours in the pattern. On each one only the particular pattern for one colour is shown, and this pattern is printed in its colour and then the fabric passes on to the next roller, in the same machine.

This will print that part of the design which is in one other colour, and so on.

## CHAPTER XXVIII

### MANURES

MANURES are plant foods, and in all but the most primitive of agriculture their use is known and practised. Of course in certain favoured areas the manure has been applied naturally, to the saving of labour, *e.g.* in the inundation area of the Nile and in fire-swept parts of the prairie, whilst all soils derive a large amount of their food from the atmosphere. Also certain crops actually add certain ingredients, which are foods for other plants, to the soil, but however it be done, in some way or other, certain foods, essential for specific crops, must be added.

It so happens that the waste products of animal life contain much material that is very valuable food for plants, as well as the necessary enzymes or fermentation agents to break it up, and so the excreta of animals and human beings have formed, and still form, the most important of manures. These, however, are usually of local production, and it is only rarely that such excreta form articles of general commerce, although they do under certain special conditions, *e.g.* the guano of Peru, etc., and coprolites.

Animals themselves, *e.g.* the menhaden fish and plants, *e.g.* vetch or mustard, are often used as manure, and waste products from various industries, *e.g.* castor oil cake, spent hops, etc., are also used as manure. When all these organic sources have been taken into account, however, the supply falls far short of the demand of modern agriculture, and is likely to fall still further behind in the future. Mineral substances and manufactured articles have therefore to be used, and a huge industry has developed around the supply of these. Different plants require special foods, and it is to the great advantage of mineral and synthetic manures that the particular food can be given in calculated and non-wasteful quantity. A drawback to their employment, when not used in conjunction with organic manure, is that they add nothing to the humus of the soil, and may even tend to destroy it.

**I. COMMERCIAL MANURES OF NATURAL ORIGIN.—Guano.** Guano consists of the excrement of sea birds, with residues from



uneaten food, and remains of the dead bodies of the gulls, etc., themselves. Such material when first formed has a very high manurial value, and it will continue to remain as highly efficient if it be stored in a dry place or, naturally, in the islands off the coast of the Atacama desert in South Peru, *e.g.* the Chincha Isles. These islands formed for some time a great supply of guano of the best quality, but they became exhausted. Now, however, the gulls, etc., are protected, and a fresh supply is obtained and marketed every year.

Where guano is subject to wetting by rain, as of course is the case in most regions of the world, the nitrogen which it contains is converted into ammonia, which is volatile and passes off or is washed into the soil and away. (A similar decomposition is the cause of the strong ammoniacal smell of stables.) This does not mean, however, that the guano is then worthless, for it still contains a high percentage of phosphorus which is next after nitrogen the most important plant food that must be artificially supplied.

**Coprolites** are nodules of impure calcium phosphate (containing calcium carbonate) about 3 in. long and 1½ in. wide. They are the fossilized excrement of ichthyosaurs, and are found in regions that were, and often are, swamps, *e.g.* Cambridgeshire. There are also nodules of calcium phosphate found in the green sand, which are called pseudo coprolites, and which appear to be aggregations of inorganic origin. Coprolites and pseudo coprolites, when used at all as phosphatic manures, are usually manufactured into calcium superphosphates.

**Hoofs, horn waste after manufacture, dried blood and slaughter house refuse** form very valuable manures, and are always used as such unless there be competition for them which makes their price too high. They are chiefly valuable as nitrogenous manures.

**Scrap leather** which has been treated with superheated steam (torrified leather) is sometimes ground up and used as a manure, but it does not appear to be of very much use since, of course, tanning has preserved it from decomposition and plants cannot use the nitrogen it contains until it decomposes.

**Meat meal or meat guano** is the dried and ground refuse after lean meat has been boiled to form meat extract. Sometimes also the carcasses of diseased animals are similarly converted. In such

cases the bones are frequently treated along with the meat and the product is then called phosphatic meat guano.

**Fish guano** is prepared from the dried offal of fish and from fish, when there is a glut, or from whales, etc. If there is no bone the manure is nitrogenous, but the addition of bone makes it partly phosphatic. Both meat guano and fish guano are valuable manures.

**Shoddy and waste wool** (noils) contain a relatively large quantity of nitrogen, but they decompose so slowly that unless they are composted they are not of much use. They are used, however, for hop gardens.

**Soot** contains nitrogen which is, very easily indeed, converted into ammonia and as such is a useful manure, especially as it also acts as an insecticide.

**Bone meal and bone ash** are sometimes used directly as manures or they may be manufactured into superphosphate of lime. They are slow acting manures.

**Sewage.**—A very important and increasingly used manure is the product from sewage farms.

**Seaweed** is often applied directly to the soil as manure in coastal districts.

**NITROGENOUS MANURES OF INORGANIC ORIGIN.**—**Sodium Nitrate** (Chile saltpetre, cubic nitre) is found in huge deposits some 3,000–4,000 ft. above sea level in the rainless Atacama desert. It is not strictly true to call it a manure of inorganic origin since it has quite possibly been produced by the action of nitrifying bacteria upon accumulations of sea weed. That, however, must have been in the distant past. The sodium nitrate has remained in the soil instead of being dissolved out because the region where it is found is in the heart of the South East Trade Wind and in the lee of the Andes. It is therefore rainless.

The crude Chile saltpetre is called “caliche,” and occurs in a layer beneath the surface. It is blasted out, separated from foreign rock, and then dissolved in water and crystallized out. Many of the valuable impurities, *e.g.* iodine, remain behind in the mother liquor and the commercial product usually contains about 95 per cent of sodium nitrate.

The available supplies are very large. It was recently estimated that there were 120,000,000–220,000,000 tons capable of being

utilized, and at a normal rate of increase of consumption this should last for from 50 to 100 years. But, of course, long before that time the price would have increased too greatly to permit of its general use. It should be pointed out, moreover, that much of this is in a fuel-less and waterless region. Steps have therefore been taken to manufacture calcium nitrate, which is an efficient substitute, on a large scale, and at competitive prices. There are works in various parts of the world (usually where there is an abundance of water power), but a brief description of the Birkeland and Eyde process, carried out at Notodden, in Norway, will suffice.

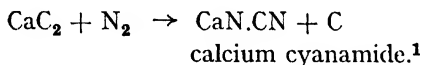
The essential problem is to get the nitrogen of the air into suitable combination, and in this case it is made to combine with oxygen. There is thus in the atmosphere an almost inexhaustible supply of raw material.

The plant consists of two water-cooled hollow copper electrodes. A powerful alternating current is passed between them, and the arc so produced is deflected at right angles to the electrodes by enormous electro magnets. Under such conditions oxygen and nitrogen burn together in a huge circular flame or arc, about 2 metres in diameter. The supply of air is maintained by fans and the resulting nitric oxide gas ( $N_2 + O_2 = 2 NO$ ) is very rapidly cooled so as to prevent dissociation. By this means about  $1\frac{1}{2}$  per cent of the gases leaving the furnace is nitric oxide, and this, of course, when cool, at once unites with oxygen from air to form nitrogen peroxide ( $2 NO + O_2 = N_2O_4$  or  $2 NO_2$ ). This gas is then absorbed by water in a tower and then neutralized by milk of lime (calcium hydroxide) in other towers. The calcium nitrate solution so produced is evaporated practically to dryness and sold as "Norwegian saltpetre." It has suffered somewhat in the past by being so finely ground as to be difficult to handle, blowing about in the wind if hand-applied, or dropping too freely if drilled in, but by now this difficulty has probably been surmounted.

Nitrate manures, *i.e.* sodium or calcium nitrate, are very quick acting, and since they are very soluble must be applied at the right time, when the crops are growing, especially on light soils, otherwise they will be washed out of the ground. They are particularly useful for grasses, either natural or cultivated, *i.e.* cereals, and form the best nitrogenous wheat manures known.

**Calcium Cyanamide** (Nitrolim, Kalkstickstoff), is another important manure providing atmospheric nitrogen in a form which the plants can assimilate. This substance is prepared by the action of nitrogen upon calcium carbide.

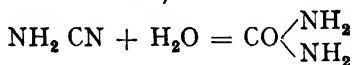
The carbide is made (principally in Sweden) by heating together lime and anthracite in the electric furnace at about  $3,000^{\circ}\text{C}$ . The cooled calcium carbide is finely crushed (being at the same time kept dry). This is then put into closed vessels and nitrogen (from a liquid air fractionation plant) passed in under pressure. The mass is then electrically heated up to about  $800^{\circ}\text{C}$ . and the reaction commences, and, after it has started, practically proceeds to a conclusion without further external heat supply.



The black mixture of calcium cyanamide and carbon is then powdered and marketed under the name of nitrolim. It is supplied chiefly by the North Western Cyanamide Co., of Odda, Norway.

Nitrolim is, when pure, a valuable nitrogenous manure, and it is a great pity that first samples should have contained some cyanide which is a plant poison. It is not so good when used as a top dressing as when dug in.

It appears to become very easily assimilable by plants, being converted by carbon dioxide, the water of the soil, and atmosphere into cyanamide ( $\text{CaN, CN} + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CaCO}_3 + \text{H}_2\text{N, CN}$ ). The cyanamide is then converted into urea (the substance of well-known manurial value in urine)—



and the urea is then rapidly converted into ammonia via ammonium carbonate and thence into nitrate.

Cyanides (for gold extraction) and nitric acid are prepared from calcium cyanamide.

**Ammonium Sulphate** ( $(\text{NH}_4)_2\text{SO}_4$ ) is a very valuable, quick-acting, nitrogenous manure which is produced in very large quantity as a by-product in the distillation of coal, in the preparation of Mond gas, and from shale and iron works. It is also made

<sup>1</sup> Cyanamide is  $\text{H}_2\text{N.CN}$ .

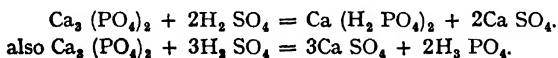
commercially from "nitrolim," and directly by the interaction of nitrogen and hydrogen to form ammonia, and neutralization of the ammonia.

It is soluble in water, although not so much so as is sodium nitrate and so it is best applied to growing crops. It gives better results on well-limed soil.

#### **MANUFACTURED AND MINERAL PHOSPHATIC MANURES.—**

Most of the natural phosphates and phosphites described under PHOSPHORUS can be used as manures in either the natural or the manufactured condition. The chief supplies of raw material come from Algeria and Florida, although, of course, phosphatic minerals are very widely distributed in Nature. It is noteworthy that the import of crude phosphates, etc., into the United Kingdom exceeds 500,000 tons yearly. Much of this supply is converted into calcium superphosphate, and the preparation of that substance will be briefly described.

**Calcium Superphosphate** is made by very finely grinding the natural phosphate and then stirring it with fairly strong sulphuric acid for about two minutes. The mass is allowed to fall into a "pit" in which it solidifies and from which it is cut by rapidly revolving knives. The superphosphate is then ground up—



It follows from the process of manufacture, therefore, that calcium superphosphate contains calcium sulphate and phosphoric acid. When first prepared it is soluble in water, but water converts it into  $\text{CaHPO}_4$ , which is not so soluble (reverted phosphate) and is not so valuable as a manure. This reversion is particularly noticeable with phosphates containing iron and aluminium. If the calcium sulphate be removed and the quantity of  $\text{H}_3\text{PO}_4$  be large superphosphates of very high manurial value result. They are sometimes called double superphosphates.

Superphosphate is one of the best of all manures for root crops and for peas and beans. It is best supplied by itself in the late winter. It may be mixed with ammonium sulphate, but it is undesirable to mix calcium superphosphate with any other manure than this.

**BASIC SLAG.**—It has already been mentioned under IRON AND STEEL that pig-iron from phosphatic and silicious ores has to be made into steel in a lime or dolomite-lined Bessemer converter. The basic lining combines with the phosphorus and silicon and produces a light fusible slag which floats on the iron and is poured off. This "basic slag" is then stamped into pieces and milled into a very fine powder; 100 lb. of such a slag are, on the average, equal in manurial value to about 35 lb. of calcium superphosphate.

The phosphorus is present as a basic calcium phosphate, and this substance is much more soluble in dilute carbonic acid (of which soil water partly consists) than are normal phosphates. It is a manure of slow action and is best applied, to heavy lands, in the autumn.

**POTASH MANURES.**—After calcium, the chief mineral matters in the bodies of plants are salts of potassium and about 10 per cent of plant ash consists of potassium carbonate ( $K_2CO_3$ ). It follows, therefore, that potassium in some form or other must be an essential plant food. Primitively this has been applied in the form of wood and plant ash, but it stands to reason that with intensive cultivation an increase in the supply available from this source is necessary.

As a matter of fact natural mineral supplies of potassium compounds, which can be easily worked, are extremely localized, and those of Stassfurt, in Germany, of Alsace, and some not yet worked in Spain (near Barcelona), are the only ones of any great importance at present. Ordinary clay and felspar contain potassium, and it cannot be long before supplies of potash obtained from felspar will be placed on the market. A great deal of work has already been put in on this problem; it is largely a question of fuel. Potassium available for plant use is present in blast furnace dust, and this substance has been used, during the war, as a manure. Some has also been obtained from Lake Serles, in California, and the natives of Bengal have for long used local supplies of saltpetre.

Potassium salts are present in sea-water, but it does not at present pay to evaporate and extract them.

Despite all these possibilities, therefore, the practicable commercial sources are really only two in number—those of Stassfurt and of Alsace.

The Stassfurt deposits contain sylvine (from 70 per cent potassium chloride) and impurer varieties of the chloride called sylvinite. Carnallite, magnesium potassium chloride ( $\text{KCl Mg Cl}_2 \cdot 6 \text{ H}_2\text{O}$ ), Schonite ( $\text{Mg SO}_4 \text{ K}_2\text{SO}_4 \cdot 6 \text{ H}_2\text{O}$ ), Polyhalite (potassium, magnesium, calcium phosphate), which contains about 25 per cent potassium sulphate and kainite, which is potassium sulphate in combination with the chloride and sulphate of magnesium. Of these the one most frequently used as a manure is kainite.

The foregoing do not include all the possible plant foods, but they do include those most usually applied and in general the less important articles of diet for the plant are obtained from the soil, air, water, or from impurities in the manures given.

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